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MARINE ICHTHYOPLANKTON ENTRAINMENT STUDIES

VOLUME II
ANALYSIS AND INTERPRETATION

AUGUST 1979 - SEPTEMBER 1980

Section 316(b)
Federal Water Pollution Control Act

Ormond Beach Generating Station
Redondo Beach Generating Station, Units 5 & 6 and 7 & 8
San Onofre Generating Station, Unit 1

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SOUTHERN CALIFORNIA EDISON COMPANY

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SUMMARY

This report presents results of a program designed to assess patterns of entrainment and transit success of fish larvae in representative generating station cooling water systems. The combined studies were initiated in August 1979 and completed in September 1980.

The generating stations involved in the study were Ormond Beach Generating Station, Redondo Beach Generating Station Units 5 and 6 and 7 and 8, and San Onofre Nuclear Generating Station Unit 1. The sites were selected based on a physical and biological categorization study of SCE system stations.

The entrainment inventory and mass balance studies were designed to provide quantitative information in support of a demonstration to satisfy Section 316(b) of the Amendments to the Federal Water Pollution Control Act of 1972 (FWPCA). The following are individual summaries of each study element:

ENTRAINMENT INVENTORY

Samples of entrained ichthyoplankton were collected monthly by pump from within the intake risers of four SCE generating stations concurrent with offshore sampling. Sampling was conducted at each intake between August 1979 and July 1980. Four samples of 100 m³ were collected during each of six two hour periods over one 24-hr day. Daily, monthly, and annual entrainment of ichthyoplankton larvae at each site was estimated utilizing observed larval entrainment concentrations and maximum designed station cooling water flows.

1. Estimates of total annual ichthyoplankton entrainment were highest at Redondo Beach Units 7 and 8, followed by Ormond Beach, San Onofre Unit 1, and Redondo Beach Units 5 and 6. Although a considerable variety of species was taken at each intake over the year, a small number of taxa dominated the catch. Entrained ichthyoplankton at intakes influenced by offshore waters were dominated by abundant species that spawn pelagically, while intakes located near harbors or breakwaters entrained representatives of communities inhabiting rocky or soft mud substrates. Intakes influenced by several types of habitats displayed the greatest variety of species entrained.

2. Larvae of northern anchovy, white croaker and queenfish dominated the overall entrainment at the three offshore intake sites. Gobies, blennies, and clinids were the dominant groups at the fourth site. These taxa were major contributors to entrained larval concentrations during all months at all four stations.

3. Seasonal trends in species entrainment were similar among open coast stations, where peak abundances were consistently noted during the spring.

4. Entrainment abundance and composition was primarily affected by nearby habitat types, vertical migration, and visual avoidance. Tidal height and stage, sea state, and temperature and salinity profiles in the water column were less important.

5. No significant differences were noted between intakes in the size frequency distributions of entrained target species larvae, the majority of which were observed in size classes of less than 6 mm length. Reduced entrainment of larger classes was attributed to avoidance, reduced abundance of larger size groups, and life history habits of the species examined.

6. A comparison of entrainment data from this study at San Onofre Unit 1 to data from previous studies at the same site indicated a substantial shift between years to the entrainment of smaller size classes in the current study, possibly due to changes in adult spawning activity or modified larval survivorship rates.

7. All calculations of entrainment were based on maximum rated intake flow volumes at each station. Operating records at sampled stations indicate that actual annual flow volumes may be 10-20% lower than maximum rated flows, resulting in significantly lower numbers of plankton entrained.

ENTRAINMENT MASS BALANCE

Ichthyoplankton samples were collected concurrently from intake and discharge conduit risers at San Onofre Unit 1 and Ormond Beach to determine success of transit through the cooling system. The mass balance studies were conducted before and after biofouling control and were planned for both winter and summer seasons. Two 24-hr surveys were conducted at San Onofre Unit 1, and three 24-hr surveys were conducted at Ormond Beach. Sampling protocol at both the intake and discharge were identical to that described in the entrainment inventory portion of this study. A suitable lag time allowed sampling of the same water parcel at both intake and discharge locations.

1. Species composition of the larval communities entrained at each site were similar to those described in the entrainment inventory section of this study. Both studies were dominated by a small number of taxa that greatly influenced the indicated overall larval transit success. Collections at San Onofre Unit 1 in March 1980 were dominated by larvae of northern anchovy, white croaker, and queenfish, with lesser roles played by unidentified yolk sac larvae, jacksmelt, gobies, and California halibut. Samples taken at Ormond Beach in September 1980 were comprised mainly of northern anchovy, cheekspot goby, queenfish, and Mexican lampfish. Larval concentrations observed at Ormond Beach were much lower than densities observed at San Onofre. Seasonal and diurnal occurrence and density of the larvae were similar to those observed in the entrainment inventory portion of this study.

2. The majority of entrained larval species experienced substantial losses during station transit at San Onofre Unit 1. The low ratios of transit success were related to the dominance of small individuals

(< 6 mm S.L.) of 316(b) target species. Larger size classes generally experienced greater transit success. No trends were noted relating transit success to water column temperature, tidal height, sampling period, or numbers of larvae entrained during different sampling periods. The most significant factor determining species transit success appeared to be the size of the individual larva.

3. Station transit success was much higher for many species at Ormond Beach than at San Onofre Unit 1, even in smaller size groups of the same species. Larvae of target species were less dominant than at San Onofre, but overall transit success was still strongly influenced by a relatively small number of taxa. Overall transit success during each phase conformed closely with the predicted effect of fouling community biomass on entrained larval abundance; i.e. greater success following biofouling control.

4. Overall, high variability characterized the results of the mass balance study. Changing sampling sites (generating stations) due to an extended outage at San Onofre Unit 1 no doubt induced substantial variability. Other factors included large overall variability encountered in species composition, size frequency distributions, and abundances among sampling periods. Also, the expected changes in ambient water temperature (i.e. peaking in September) did not occur.

5. The mean annual transit success ratio is roughly estimated to be near 44% of intake entrainment, based on comparative density and success rates of larvae at the two study sites.

CHAPTER 1

INTRODUCTION

REPORT ORGANIZATION AND APPROACH

Volume I of this report includes a comprehensive presentation of all raw data collected at four SCE generating stations during the entrainment inventory and mass balance phases of this study.

Entrainment inventory and mass balance comprise separate chapters in this volume. All objectives and results associated with each element are addressed in that chapter.

Each chapter contains a separate introduction followed by a background of the subject studies at SCE generating stations through 1980. In order to facilitate complete and timely review of major ideas, the overall discussion follows the background, which is then followed by 316(b) study detailed methods, results, and analyses.

STUDY OVERVIEW

The Ichthyoplankton Entrainment Inventory and Mass Balance Study program conducted for the Southern California Edison Company (SCE) was designed as part of an overall 316(b) Demonstration Study Plan to satisfy the requirements of the Amendments to the Federal Water Pollution Control Act of 1972. Section 316(b) states that "any standard established pursuant to Section 301 [point source effluent limitations] or Section 306 [Federal standards of performance] of this Act and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." These studies were designed to answer several questions relating currently operating SCE technology to Federal requirements.

The studies consisted of two elements: 1) an entrainment inventory; and 2) a mass balance study. The entrainment element was directed at estimating larval fish withdrawal at four generating station study sites, while the mass balance element determined changes in ichthyoplankton concentrations between intake and discharge sampling sites. Study objectives included determination of: 1) the quantity of plankton entrained; 2) intake withdrawal patterns; and 3) percent transit success of entrained ichthyoplankton larvae. Mortality studies would be conducted only if overall transit success was significant (i.e. >60%). A chronological summary of SCE marine larval fish entrainment studies is presented in Table 1.

A physical and biological categorization process to provide guidance for selection of SCE representative 316(b) study sites (Schlotterbeck et al. 1979a) was developed. The objective was to determine if representative intake study sites could be identified to fulfill the requirements of Section 316(b) for SCE coastal generating stations. Since the scope of these studies is substantial, it was not economically feasible nor technically necessary to intensively study all elements at each intake site. The overall 316(b) demonstration was designed to maximize the collection of data relevant to the minimization of adverse environmental impact, rather than conduct redundant sampling at similar stations. By determining physical and biological similarities among intakes, a more intensive

Table 1. Chronological history of SCE larval fish entrainment studies.

Year	Month	# of Surveys	Stations	Periods	Replicates/Period	Pumping Duration (min)	Comments
<u>STUDY PROGRAM</u>							
<u>San Onofre Preoperational Special Study</u>							
1977	Aug-Sep	1	San Onofre 1	day, night	4	60	1 m standpipe
	Oct	1	San Onofre 1	day, night	4	60	3 m standpipe
	Nov-Dec	2	San Onofre 1	day, night	8	30	Shorter pump duration resulted in less damage to pumped larvae
1978	Jan	1	San Onofre 1	day 1, day 2 night	8 day 8 night	30	Day period split 0900-1100; 1300-1500
1978-79	Feb 78-Jul 79	17	San Onofre 1	2 day, 2 night 2 crepuscular	4	30	24 samples in 6 periods reported in 80-RD-100
<u>316(b) Methods Development</u>							
1978	May	1	Redondo Beach Units 7 & 8	-	14 total	30	Comparison of intake and water column concentrations at several vertical locations near intake opening and concurrent dye releases
1978	Jun	1	Offshore Newport Beach	day, night	10	10	Comparison of simultaneous collections of pump and towed Bongo samples indicate net and pump samples not statistically different
1978	Aug	1	San Onofre 1	day, night	16	30	Comparison of ichthyoplankton and zooplankton concentrations using 2 sampling devices to determine representative sampling location reported in 79-RD-69
<u>316(b) Entrainment Inventory</u>							
1979-80	Aug 79-Jul 80	12	Ormond Beach Redondo Beach Units 5 & 6 and 7 & 8 San Onofre 1	2 day, 2 night 2 crepuscular	4	30	Monthly samples at four stations within a 10-day period
<u>316(b) Entrainment Mass Balance</u>							
1980	Mar	2	San Onofre 1	2 day, 2 night 2 crepuscular	4	30	Mass balance determined by comparing simultaneous samples from intake and discharge risers, two different phases of bio-fouling control cycle (winter season)
1980	Sep	3	Ormond Beach	2 day, 2 night 2 crepuscular	4	30	As above over three bio-fouling control cycle phases (summer season)

sampling effort could be conducted at fewer representative generic sites. Although some aspects of the overall program were investigated at each generating station, increased sampling intensity at fewer intake sites was more scientifically credible and economically feasible.

REPRESENTATIVE SAMPLING SITE SELECTION

Southern California Edison Company operates eight coastal facilities with thirteen independent intakes. Because of biological and physical similarities, it is not necessary to study all intakes. Data acquired at representative sites may be utilized to extrapolate and predict effects at unsampled, but similar, intakes. The criteria for site selection was based on intake type, geographic range, biological and physical similarity, and intakes where other studies were conducted.

A categorization study produced to justify representative sampling sites to regulatory review agencies (Schlotterbeck et al. 1979a) examined the biological and physical aspects of Edison intakes. Seven intakes are located offshore (Ormond Beach, El Segundo Units 1 and 2, El Segundo Units 3 and 4, Huntington Beach, San Onofre Unit 1, and San Onofre Units 2 and 3), one at the mouth of King Harbor (Redondo Beach 7 and 8), and five are harbor or canal intake systems (Mandalay, Redondo Beach Units 1-4, Redondo Beach Units 5 and 6, Long Beach, and Alamitos). A summary of the categorization study findings is:

"All intake systems at Southern California Edison coastal stations were categorized by physical and hydraulic engineering characteristics. All velocity cap intakes were grouped by cap type (overhang cap, flush cap, overhang cap and riser) and intake velocity. The protected intakes were classed as either canal or embayment intakes, with the exception of Redondo Beach Units 1-4 and 5 & 6 which are offshore intakes within a harbor.

"Biological categorization of intake locations defined two major intake types: exposed coast and protected areas. Exposed intakes with sandy substrate at Ormond Beach, El Segundo, and Huntington Beach were further distinguished from San Onofre and Redondo Beach Units 7 and 8 which are located in areas of stable substrate. The intakes in protected areas were divided into an embayment/canal group including Long Beach, Alamitos, and Mandalay and the unique Redondo Beach Units 1-4 and Units 5 and 6.

"Based on the physical and biological similarities, Ormond Beach - open ocean sandy, Redondo Beach Units 7 and 8 - open ocean stable, Redondo Beach Units 5 and 6 - harbor intake, Alamitos - embayment/canal, and San Onofre Unit 1 were chosen as representative sites for Southern California Edison 316(b) demonstrations, specifically, ichthyoplankton entrainment studies." Because the demonstration for Alamitos was to be completed by use of data from the Haynes complex (IRC 1980), San Onofre was incorporated into the existing study to provide a southern boundary for the Edison system (Figure 1).

REPRESENTATIVE INTAKE SAMPLING POSITION

A sampling point within the intake riser system which represented a mixed sample of all the water drawn into the intake was required to obtain unbiased samples. If an intake sample were biased by neuston, midwater, or epibenthic ichthyoplankton, then interpretation of results could be erroneous.

In August 1977 a permanent standpipe that extended 3 m into the vertical conduit was installed in the San Onofre Unit 1 intake riser to sample entrained ichthyoplankton as part of the SONGS Units 2 and 3 preoperational monitoring program (PMP; SCE 1980). This position was thought to provide a non-biased biologically representative sample. However, dye studies were required to determine the location of completely mixed intake waters before biological assumptions could be tested for validity. Preliminary dye studies were conducted as part of the Analysis of Intake Withdrawal Patterns study. Results at San Onofre Unit 1 (KLI 1981) indicated that the point of homogeneous mixing may be located as far as 10 to 15 m downstream in the horizontal conduit. The onshore screenwell and adjacent upstream conduit were shown not to be representative sampling sites (Barnett unpublished) because ichthyoplankton concentrations were substantially reduced at this point when compared to intake riser samples.

Once the point of homogeneous mixing was determined, simultaneous collection of plankton samples from the standpipe and the completely mixed location were required to determine if biological differences existed. A comparison study (Schlotterbeck et al. 1979b) between the theoretical mixing point defined by the

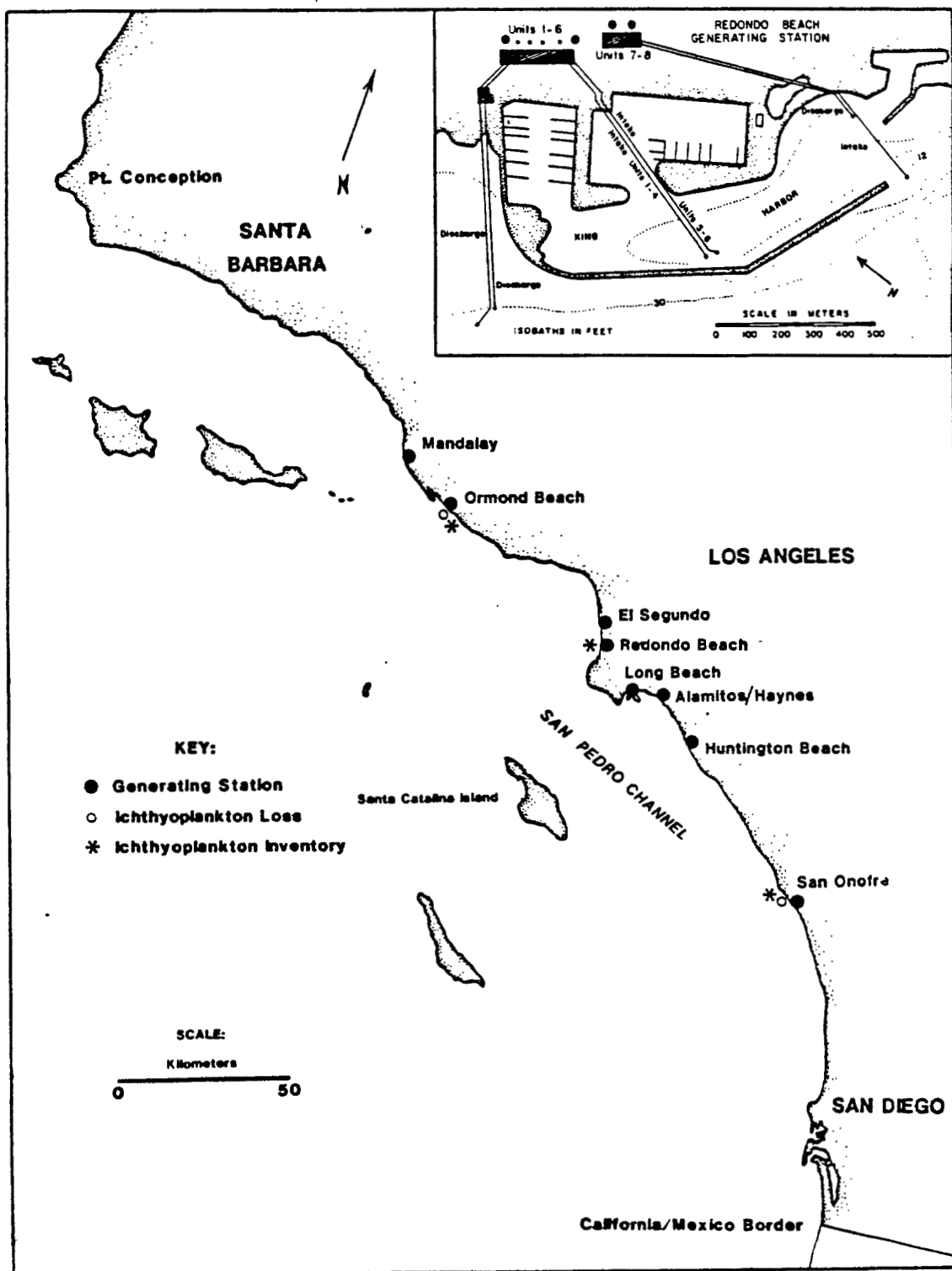


Figure 1. Sites for ichthyoplankton entrainment and mass balance studies within the Southern California Edison Company system.

dye study and the initial sampling position (3 m standpipe through the velocity cap) was conducted in August 1978 by pumping samples simultaneously from the standpipe and the projected mixing point 15 m within the horizontal intake conduit. The theoretical mixing point inside the intake conduit was sampled by a specially constructed Intake Unidirectional Diverter (IUD; Figures 2 and 3). The IUD was designed to reduce sampling bias associated with differential water velocity, turbulence, and conduit wall effects. Thirty-two replicate samples of 100 m³ were collected during a 24 hr period to evaluate the effectiveness of

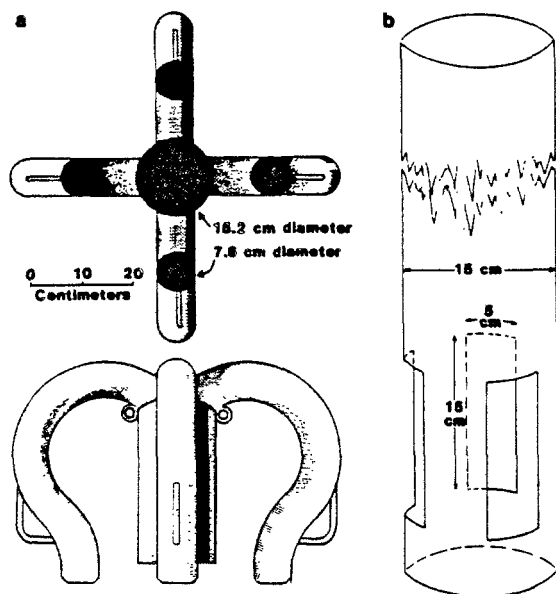


Figure 2. Intake sampling devices: a) front and side view of the curved port Intake Unidirectional Diverter (IUD) device; b) standpipe.

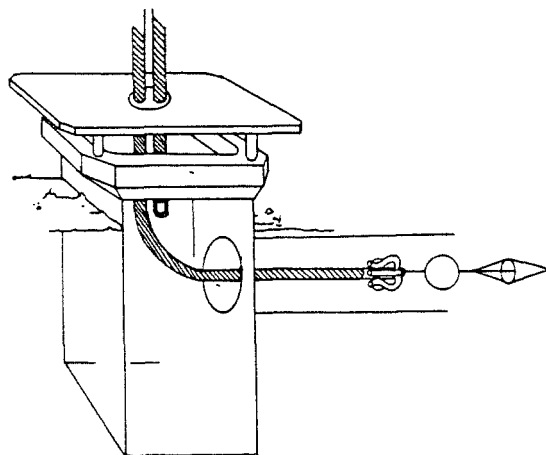


Figure 3. Schematic diagram of deployment of the IUD through the velocity cap and horizontal section beyond the cooling system intake riser at San Onofre Unit 1.

both the IUD and existing standpipe. A Wilcoxon matched pairs signed-ranks test applied to ten size classes of fish larvae (3 mm increments from 0 to 30 mm) indicated no statistical difference between the standpipe and IUD; however, the standpipe was significantly more effective in collecting northern anchovy and queenfish. The IUD was not as effective as the standpipe in collection of larvae smaller than 9 mm.

The 3 m standpipe was selected as the preferred ongoing intake sampling device because: 1) it more effectively collected ichthyoplankton samples, 2) there was no difference between the standpipe and IUD in similarity to longshore tow collections, and 3) the standpipe was logistically easier and safer to install and retrieve than the IUD while the generating station was in operation (Schlotterbeck et al. 1979b).

Subsequently the access manhole of the intake at each of the four 316(b) sampling sites was modified in August 1979 to receive a fiberglass standpipe, which was connected to a 15.2 cm diameter hose leading to the fish pump during sampling (Figure 4).

TARGET AND KEY SPECIES SELECTION

Certain fish species received substantially more analysis than others. These species were referred to as target species, and criteria established for their selection included: 1) importance in the local trophic structure (either as planktivorous, piscivorous, or benthic feeders, and importance as a food source); 2) presence in the study area with at least minimal abundance during most periods of the year to lend statistical integrity to analyses; 3) species subject to high degrees of

entrainment and impingement during most of their life history; and 4) species which, if adversely impacted, might result in community level effects. Based on these criteria, target species chosen for study were northern anchovy (*Engraulis mordax*), white croaker (*Genyonemus lineatus*) and queenfish (*Seriphus politus*).

In addition, all 316(b) target and key species (Table 2) were measured. The criteria for selection of 316(b) key species was presented by Wintersteen and Dorn (1979). These species include the three target species and white, walleye, and shiner surfperch (viviparous-no larvae), kelp bass, barred sand bass, sargo, spotfin croaker, bocaccio, and Pacific butterfish. Additionally, the California Department of Fish and Game recommended the addition of yellowfin croaker, black croaker, and black surfperch (the latter also viviparous).

APPLICATION OF STUDY RESULTS

The results of the entrainment inventory were utilized to develop loss estimates for the entire SCE system. A concurrent 316(b) study by the University of Southern California, Institute of Marine and Coastal Studies (IMCS) determined abundance and distribution of ichthyoplankton in the nearshore zone (<75 m) of the Southern California Bight, an area extending from Point Conception in the north to the California/Mexico border on the south (Figure 1). The IMCS study was designed to allow calculation of an estimated entrainable resource against which the magnitude of entrained ichthyoplankton abundance could be compared.

Results of the mass balance study were used to formulate a standard against which proposed improvements in technology could be measured. Concurrent studies by Lawler, Matusky, and Skelly, Engineers were directed to examining the potential for diversion or exclusion of larval forms through louver, dike, or fine-mesh screen technologies. The projected success rates of these technologies in reducing larval entrainment mortality could be compared to observed station transit success (and potentially mortality) for determinations regarding "best technology available."

The effects of "location, design, construction, and capacity" of cooling water intakes were evaluated in separate studies on larval and adult fishes by Thomas et al. (1980a-b), Herbinson (1981), Helvey (1979, 1980, and 1982), and LMS (1981). A progress report incorporating objectives and materials and methods utilized in the entrainment and other phases of the overall 316(b) demonstration was submitted to three California Regional Water Quality Control Boards in December 1979 (SCE 1979b).

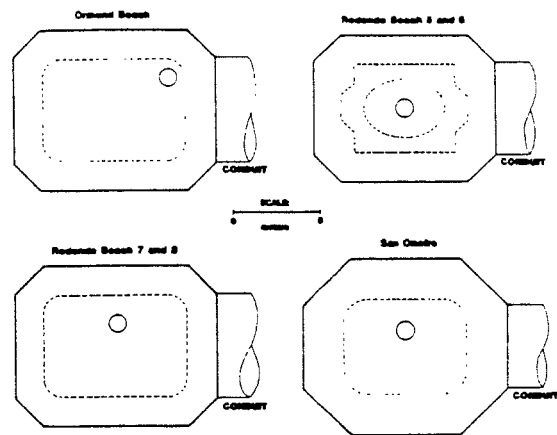


Figure 4. Comparative configuration of the intake riser velocity caps at the four entrainment study sites.

Table 2. 316(b) target species.

Species	Common Name
1. <i>Engraulis mordax</i>	northern anchovy
2. <i>Genyonemus lineatus</i>	white croaker
3. <i>Seriphus politus</i>	queenfish
4. <i>Cheilodroma saturnum</i>	black croaker
5. <i>Umbrina roncadore</i>	yellowfin croaker
6. <i>Roncadore stearnsi</i>	spotfin croaker
7. <i>Paralabrax clathratus</i>	kelp bass
8. <i>P. nebulifer</i>	barred sand bass
9. <i>Anisotremus davidsoni</i>	sargo
10. <i>Sebastes paucispinis</i>	bocaccio
11. <i>Peprilus simillimus</i>	Pacific butterfish

Water Quality Control Boards in December 1979 (SCE 1979b).

CHAPTER 2

ENTRAINMENT INVENTORY

INTRODUCTION

From August 1979 through July 1980, ichthyoplankton samples were collected monthly from the intake risers of four coastal generating stations in the Southern California Edison (SCE) system. The sampling sites were Ormond Beach, Redondo Beach Units 5 and 6 and Units 7 and 8, and San Onofre Unit 1 (Figure 1). The 12-month sampling program was designed to satisfy a requirement for estimates of SCE system entrainment losses for comparisons to offshore larval studies in a 316(b) compliance demonstration.

The purpose of this chapter is to: 1) describe the species composition, abundance, and diel behavior of ichthyoplankton larval populations entrained at four representative intake cooling systems; 2) describe the size frequency distributions of these entrained populations; 3) estimate the monthly and yearly entrainment of larvae at these intakes; and 4) discuss the factors influencing abundance, species composition, and size frequency of larval entrainment, and the applicability of these factors to these and other SCE cooling water systems.

A separate volume (SCE 1982) includes all the data used in the preparation of this report, including replicate concentrations ($\#/1000m^3$) for all larvae, size frequency histograms for 316(b) target species larvae, and temperature-salinity profiles observed at each intake during each sampling period.

BACKGROUND

Entrained ichthyoplankton samples have been collected monthly at the San Onofre Unit 1 intake since August 1977. Initial sampling efforts were conducted to develop methods for use in complying with 316(b) requirements, and as a preoperational monitoring study of the effects of San Onofre Units 2 and 3 on nearshore ichthyoplankton populations (Table 1).

During the 316(b) ichthyoplankton entrainment program, monthly samples were collected from four representative sites within the SCE system.

CHARACTERISTICS OF STUDY SITES

The Ormond Beach intake is situated on the open coast at a depth of 11.0 m MLLW (Figure 1). The middle of the 1.2 m intake opening is located 6.7 m below MLLW. Substrate in the vicinity of the intake is sand; however, the Hueneme Canyon, located 4.3 km north of the intake, influences the species composition near the intake. The station is located on open coast with primarily southwest exposure. Winds and swell are primarily from the northwest, passing down the Santa Barbara Channel between the Channel Islands and the mainland. Bottom slope in the area of the intake is approximately 1.7%.

The Redondo Beach Units 5 and 6 intake is located within King Harbor. The intake is located approximately 17 m from the jetty at a depth of 9.1 m MLLW (Figure 1). The 1.2 m intake opening is located 4.6 m below MLLW, and the local substrate is fine sediment. The narrow harbor entrance opens along the coast in a south-southeast direction. Swell exposure at the entrance is generally westerly. Waters inside the harbor are essentially cut off from open coastal circulation as

well as from wave and surf-induced turbulence. Exchange of water with the open ocean is restricted and depends largely on both tidal flow through the harbor's entrance and the intake of relatively large volumes of plant cooling waters within Redondo Harbor. Solar heating throughout most of the water column, limited turbulent mixing and a slow exchange rate with open ocean water are natural factors which increase water temperatures within the harbor, especially in the shallow mooring basins. The predominant biological community is associated with the breakwater/reef and harbor mud habitats. During September 1979, the Unit 1-4 intake, adjacent to Units 5 and 6, was sampled because circulation pumps at Units 5 and 6 were inoperative.

The Redondo Beach Units 7 and 8 intake is located at the mouth of King Harbor at a depth of 14.0 m MLLW. The intake opening is located 9.8 m below MLLW at the head of Redondo Canyon (50 m offshore), and is approximately 60 m from the jetty terminus (Figure 1). The substrate in the immediate vicinity of the intake is riprap and sand. The harbor lies at the southerly margin of Santa Monica Bay. The area outside the harbor is a typical coastal area lying within the natural protection of the Bay. Water circulation in this area results from a combination of current systems, winds, and tides. Wave refraction due to the bottom topography and the harbor's breakwater has a substantial effect on the nearshore drift of the water near the intake. The primary influences on local biology include the breakwater, harbor, sandy substrate and the Redondo Submarine Canyon.

The San Onofre Unit 1 intake is located on open coast. The location of the middle of the 1.2 m intake opening is 3.5 m below MLLW over a bottom depth of 8.2 m (Figure 1). The local substrate is composed of medium to coarse sand, large amounts of shell debris, and periodically exposed boulders and cobble. The station is located on exposed open coast backed by low cliffs and foothills. Exposure is toward the southwest, and the site is subject to swells ranging from northwest to south southeast. San Mateo Point, a prominent headland, is located 5.8 km to the northwest. Longshore currents are predominantly northwest to southeast with periodic reversals (SCE 1981). Slope of the bottom in the area is approximately 0.9%. The biological community is influenced by nearby low relief reefs, sand and kelp habitats.

The major difference associated with the intake sampling sites is geographic location. Ormond Beach is located near the northern limit of the SCE system and San Onofre is the most southern (Figure 1). The distance between these stations is 158 km. The Redondo Beach complex is located near the center of the SCE system and is 63 km from Ormond Beach and 95 km from San Onofre. All four velocity caps are relatively similar in configuration (Figure 3). The Ormond Beach and Redondo Beach Units 7 and 8 velocity caps are the same dimensions. All four opening heights are the same. Ormond Beach and Redondo Beach are high volume, high entrance velocity intakes at ocean bottom depths of 10.7 m (MLLW) and 13.7 m (MLLW), respectively (Table 3). Redondo Beach Units 5 and 6 is a low volume, low entrance velocity intake, with a bottom depth of 9.1 m (MLLW; Table 3). The San Onofre intake is intermediate in entrance velocity and volume, and the bottom depth is 9.4 m (MLLW; Table 3).

SUMMARY OF RESULTS AND DISCUSSION

SUMMARIZED RESULTS

Highest overall larval entrainment levels, as well as numbers of taxa, were observed at Redondo Beach Units 7 and 8, where the intake location at the harbor mouth resulted in contributions from rocky reef (breakwater), pelagic, and deep water (canyon) communities.

Table 3. Comparison of physical characteristics of sampled intakes.

	Ormond Beach	Redondo Beach 5 & 6	Redondo Beach 7 & 8	San Onofre 1
Maximum Rated Annual Volume ($\times 10^6 \text{ m}^3 / 10^{11} \text{ gal}$)	9.47/2.50	2.86/0.76	9.31/2.46	6.96/1.84
Entrance velocity (m sec^{-1})	0.82	0.37	0.76	0.67
Distance from Shoreline (m)	631	551	289	902
Intake/Discharge Conduit Length (m)	814/640	646/823	777/533	910/727
Opening Height (m)	1.2	1.2	1.2	1.2
Cap Depth (MLW, m)	6.1	4.6	9.1	3.5
Bottom Depth (MLW, m)	10.7	9.1	13.7	8.2
Cap Dimensions (m)	8.3x10.4	7.6x9.4	8.3x10.4	9.1x10.7
Cap Overhang (m)	0.6	2.1	0	1.3
Conduit Diameter (m)	4.3	3.1	4.3	3.7

A large number of taxa were collected from each of the four sampling sites (ranging from 64 at San Onofre Unit 1 to 94 at Redondo Beach Units 7 and 8; Figure 5); however, a small number of taxa dominated each community.

Several species of ichthyoplankton larvae were consistently observed at all four sampling sites. Cheekspot goby, *Ilypnus gilberti* and white croaker, *Genyonemus lineatus*, were

among the major larval forms entrained at each of the four intakes. Two other species, northern anchovy, *Engraulis mordax*, and queenfish, *Seriphus politus*, were major components of the ichthyoplankton community at all but the Redondo Beach Units 5 and 6.

During 11 of the 12 sampling months, the majority of larvae were collected during the evening and night periods. Larval entrainment at Redondo Beach Units 5 and 6 was the lowest among the four intakes examined.

DISCUSSION

The relationship between the species composition of the entrained larval community and the type of habitat present in the waters adjacent to an intake was illustrated during the investigation. As would be expected in an area such as Ormond Beach, with a substrate composed almost entirely of sand, the entrained larval community was dominated by fishes which as adults are associated with a soft bottom substrate. By comparison, the Redondo Beach Units 7 and 8 and Units 5 and 6 intakes were located within an area of multiple adult habitats. The major

larval species of the communities entrained at these two sites were equally split between those which inhabit sandy substrate and those that inhabit rocky reef or mud substrates as adults.

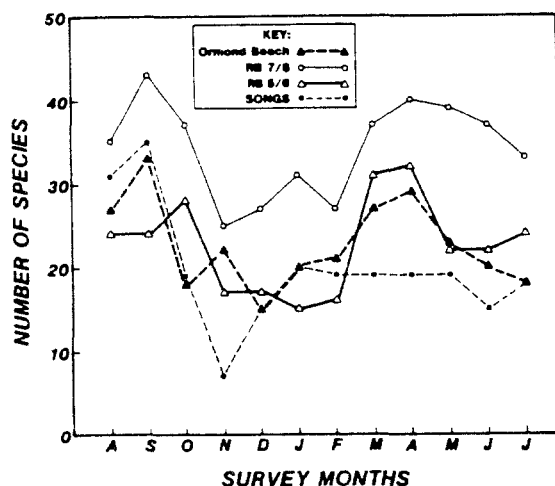


Figure 5. Number of species observed monthly in entrainment samples at four study sites.

intake, this influences much of the observed variation in larval entrainment levels. With the exception of San Onofre Unit 1, a majority of the more commonly entrained larval species represented the larval forms of demersal fishes that inhabit various nearby substrates. The importance of habitat diversity was especially apparent at the Redondo Beach sampling sites, where most of the collected species were larval forms of demersal fishes, requiring specific substrates to spawn their eggs (Table 4).

Table 4. Adult habitat and egg type of the 10 most abundant larval taxa collected by generating station.

	Pelagic	Demersal
<u>Habitat</u>		
San Onofre	5	5
Redondo Beach 7 & 8	3	7
Redondo Beach 5 & 6	0	10
Ormond Beach	3	7
<u>Egg Type</u>		
San Onofre	6	4
Redondo Beach 7 & 8	4	6
Redondo Beach 5 & 6	1	9
Ormond Beach	6	4

While entrainment levels fluctuated monthly at all four intakes, similar trends in several factors were observed at every intake, irrespective of location. Total numbers of larval species and numbers of target species collected, maximum numbers of species observed in any one replicate sample, and total numbers of larvae entrained all reached peak values during the early spring and early fall, corresponding to periods of high phytoplankton production in coastal areas (Figure 6). This phenomenon is a reproductive strategy commonly observed in zooplankton and fish species (Conover 1956, Colebrook and Robinson 1961, Steele 1974, Cushing 1975, Runge 1980) that results in hatching of larvae when food is readily available. These periods of high abundance are closely related to observed increases in stocks of 316(b) target species (except at Redondo Beach Units 5 and 6), which: 1) primarily occupy lower positions in the nearshore trophic structure; 2) are utilized as forage by piscivores; and 3) are known to be prolific spawners. Maximum larval concentrations at intakes with offshore influences were observed in the spring, with all three intakes displaying peak entrainment levels in March. At Redondo Beach Units 5 and 6, peak entrainment abundance was observed in September, at the culmination of a summer season of consistently high larval entrainment. The species composition of intake samples during this period, however, reflected the influence of the harbor

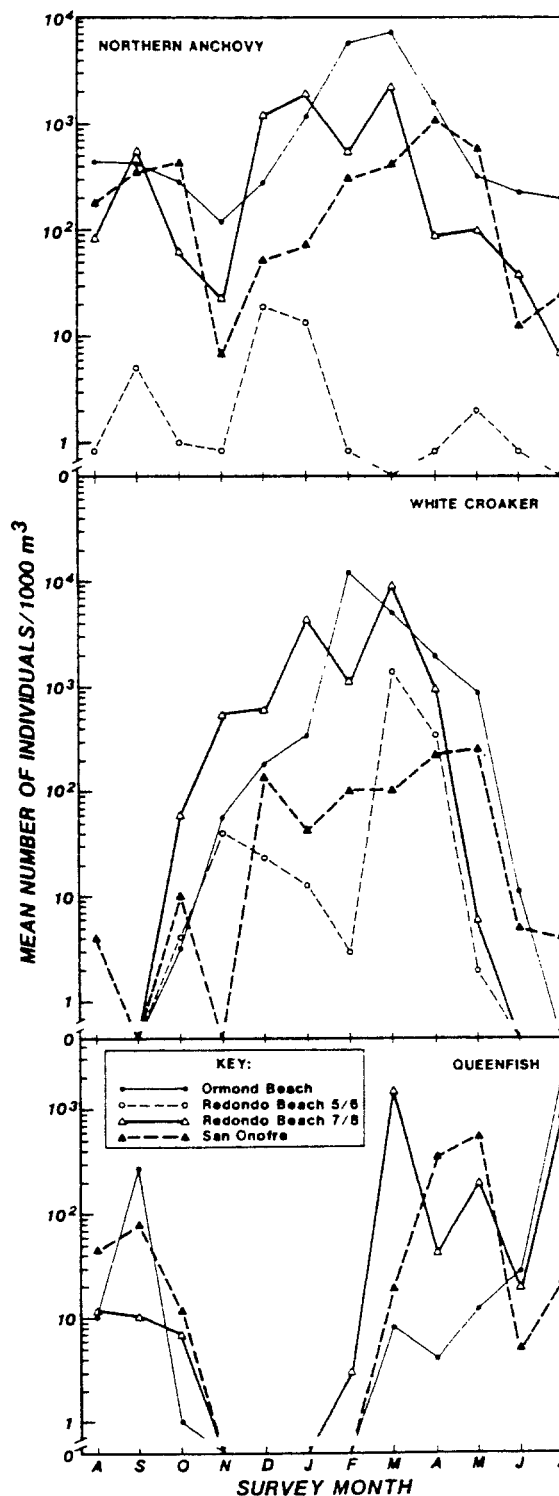


Figure 6. Monthly concentrations (number/1000m³) of three abundant target species larvae at four study sites.

and nearby breakwater. The harbor itself appears to be uninviting to the pelagic spawners that dominated peak catches at the other intakes.

Data suggest that either the tidal exchange between the harbor and offshore waters at Redondo Beach is relatively low, or the current system within the harbor is such that the Redondo Beach Units 5 and 6 intake (located adjacent to the jetty) is relatively isolated from the inward flow of offshore water during tidal exchange. Of the six common species of larvae entrained at the Redondo Beach Units 7 and 8 intake with adults that spawn outside of the harbor [northern anchovy, queenfish, California halibut (*Paralichthys californicus*), Pacific sardine (*Sardinops sagax caeruleus*), diamond turbot (*Hypsopsetta guttulata*), and hornyhead turbot (*Pleuronichthys verticalis*)], only northern anchovy and queenfish were among the top 20 taxa entrained at Redondo Beach Units 5 and 6.

Water temperature and water temperature histories outside the immediate area of the study sites may have a significant impact on the larval population susceptible to entrainment at any of the offshore intakes. This is especially true for species such as northern anchovy, with population centers located in offshore waters (Ahlstrom 1956). Northern anchovy spawn in water temperatures between 13° to 17°C off California (Kramer and Zweifel 1970). In March and April 1980, a major episode of upwelling occurred off Point Conception and the area to the north, resulting from a southerly transport of water less than 14°C. Upwelled waters were avoided by spawning adult northern anchovy (Lasker et al. 1980). Evidence of the upwelling (surface-bottom temperature comparisons) was especially prominent at Ormond Beach and Redondo Beach Units 7 and 8, while less evident at San Onofre Unit 1. The upwelling episode may be responsible for observed differences in the temporal distribution of northern anchovy between San Onofre Unit 1 and the two northernmost sampling sites by inducing a varied behavior in different groups of the overall spawning population. At Ormond Beach and Redondo Beach Units 7 and 8, the northern anchovy population exhibited a major decline during May and April, respectively, while at San Onofre Unit 1 the decline did not occur until June.

Photoperiod, which was nearly comparable at all sampled sites, may be a major cue initiating spawning and thus dictate the initial occurrence or initial density increase of many individual species, irrespective of temperature variation between sites.

Relation of Entrainment Size-Frequency to Species Ecology

Size-frequency distributions of entrained larval populations provide information on the reproductive ecology of selected target species. Previous studies (SCE 1980) have indicated that the intake is an effective sampling device for estimating offshore larval concentrations and distributions. Collections from intake samples and offshore tow tracks were very similar for white croaker and queenfish in both abundance and size-frequency distribution of captured larvae. Larvae in size classes greater than 18 mm length were rarely taken in intake or net samples. The majority of these larvae were observed in the epibenthos. Larger sciaenid larvae taken in the mid-water were most susceptible to entrainment.

The affinity of the two sciaenid target species for the epibenthos indicates that entrainment of newly-hatched individuals of these species occurs only when spawning takes place in the vicinity of the intake. Approximately 85% of white croaker larvae observed in collections at the two Redondo Beach intakes were less than 7 days old (Barnett and Sertic 1979), compared to 75% at San Onofre Unit 1 and only 55% at Ormond Beach (Table 5). Percent abundance of 3 to 6 mm larvae at Ormond Beach was 2 to 3 times greater than at any other sampled intake. These

Table 5. Yearly percent entrainment by size class of target species larvae.

Size Class (mm)	Species											
	<i>Engraulis mordax</i>				<i>Genyonemus lineatus</i>				<i>Seriophus politus</i>			
	OB	R5	R7	SO	OB	R5	R7	SO	OB	R5	R7	SO
0-3	32.1	28.1	29.8	29.4	54.5	87.2	84.8	75.3	3.1	33.4	57.4	33.1
3-6	13.8	26.0	31.8	22.4	36.7	12.6	14.8	15.0	89.9	56.7	38.8	54.4
6-9	5.7	30.5	14.5	9.3	6.5	0.2	0.4	6.7	6.8	7.9	3.5	8.3
9-12	16.3	9.3	13.3	12.4	1.7	-	<0.1	1.3	0.2	2.0	0.1	3.0
12-15	13.5	3.8	8.5	10.3	0.4	-	-	1.2	<0.1	-	<0.1	<0.1
15-18	9.7	2.1	1.8	11.0	0.1	-	-	0.3	<0.1	-	<0.1	<0.1
18-21	5.9	0.2	0.2	4.0	<0.1	-	-	-	<0.1	-	<0.1	<0.1
21-24	2.5	-	0.1	0.9	<0.1	-	-	<0.1	-	-	<0.1	<0.1
24-27	0.5	-	<0.1	0.2	<0.1	-	-	-	-	-	-	-
27-30	0.1	-	<0.1	0.1	-	-	-	-	-	-	-	-

distributions indicate that major spawning took place in closest proximity to the Redondo Beach Units 7 and 8 and San Onofre Unit 1 intakes, and somewhat further away from the Ormond Beach intake.

This trend is even more evident for queenfish, where spawning appears to have taken place nearest to Redondo Beach Units 7 and 8 and farthest from Ormond Beach. Larvae in the 0 to 3 mm size class comprised greater than 57% of total queenfish entrainment at Redondo Beach Units 7 and 8, but only 33% at San Onofre Unit 1 and 3% at Ormond Beach. An inverse pattern was observed for 3 to 6 mm larvae, ranging from 90% of total collections at Ormond Beach to 39% at Redondo Beach Units 7 and 8. Results indicate that queenfish spawn farther offshore than white croaker, since the median size of queenfish larvae entrained at each intake were larger due to the longer development time during the period between hatching and entrainment. The distribution and abundance of these two fishes is governed by behavioral patterns (feeding and reproduction) as well as physical factors (Hobson and Chess 1976, DeMartini and Fountain 1981) which may be responsible for yearly variability in primary spawning locations frequently observed at San Onofre Unit 1 (SCE 1981).

The relation of entrainment size-frequency distributions of northern anchovy larvae to spawning habit is less clear. Percent entrainment by size class was similar for all four intakes. The overall larval size frequency distribution indicated slightly larger larvae were collected at Ormond Beach, but substantial concentrations were also observed at San Onofre Unit 1 and Redondo Beach Units 7 and 8. The lack of distinct differences between intakes of varying physical characteristics attests to the ubiquitous spawning nature of this species.

Entrainment Variability Over Sampling Years - San Onofre Unit 1

Intake sampling for the 316(b) Ichthyoplankton Entrainment program extended to 30 the number of consecutive months that entrainment samples were collected at San Onofre Unit 1 utilizing current methodology. Overall mean concentrations of larvae were 20% lower (Figure 7) between August 1979 to July 1980, compared to those observed between February 1978 and July 1979 (SCE 1980). The decrease is attributable to lower concentrations of northern anchovy and white croaker during the 316(b) program. Mean annual concentrations of each of these two species decreased 40% from the previous 18 months. A 50% increase in mean concentrations of queenfish over the previous period was observed during the 316(b) program, but the overall percent composition of total entrainment represented by the three target species decreased 7% in the latter 12 months.

Comparison of percent composition of entrainment samples by size class for the three major target species (Table 6) indicated a substantial shift in size-frequency distributions during the 316(b) sampling program. In comparisons

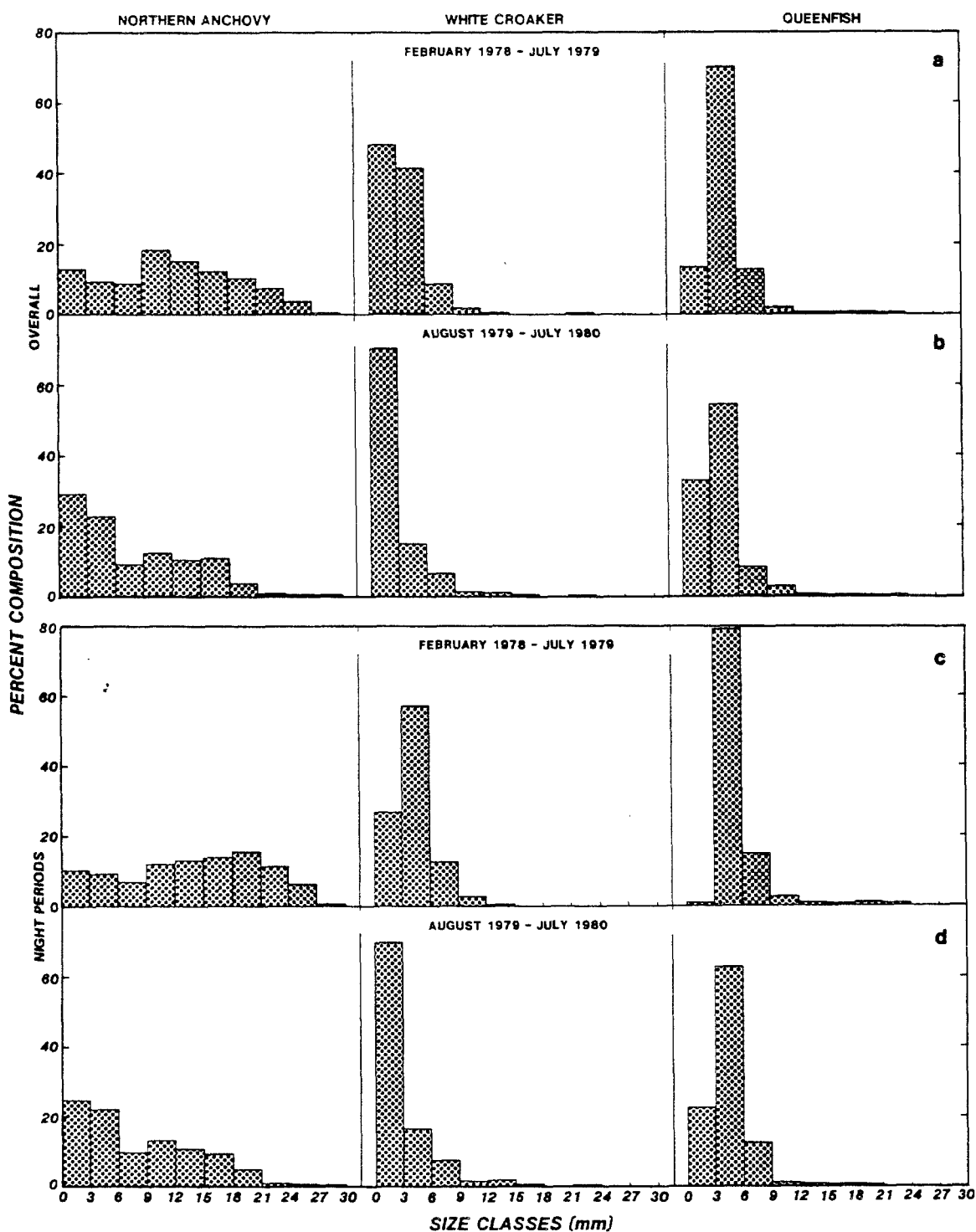


Figure 7. Comparative size-frequency distributions of three abundant target species during entrainment collections: a) San Onofre Preoperational Monitoring Program (PMP) Special Study, daily mean; b) 316(b) Ichthyoplankton Entrainment Study (IES), daily mean; c) San Onofre PMP Special Study, mean of evening and night periods only; and d) 316(b) IES, mean of evening and night periods only.

Table 6. Percent composition of mean yearly entrainment by size class and size class night periods at San Onofre Unit 1.

Size Class (mm)	<u>Engraulis mordax</u>		<u>Genyonemus lineatus</u>		<u>Seriophus politus</u>	
	Feb 78-Jul 79	Aug 79-Jul 80	Feb 78-Jul 79	Aug 79-Jul 80	Feb 78-Jul 79	Aug 79-Jul 80
<u>Overall</u>						
0-3	13.1	29.4	48.1	75.3	13.7	33.1
3-6	9.6	22.4	41.4	15.0	70.3	54.4
6-9	9.0	9.3	8.6	6.7	12.7	8.3
9-12	18.3	12.4	1.8	1.3	2.1	3.0
12-15	15.5	10.3	0.1	1.2	0.4	0.1
15-18	12.3	11.0	-	0.3	0.3	<0.1
18-21	10.3	4.0	-	-	0.4	<0.1
21-24	7.8	0.9	<0.1	<0.1	0.2	<0.1
24-27	3.9	0.2	-	-	-	-
27-30	0.3	0.1	-	-	-	-
<u>Night Periods</u>						
0-3	10.3	25.2	26.9	69.9	0.9	22.6
3-6	9.3	22.5	57.4	17.2	79.3	62.9
6-9	7.1	10.1	12.6	8.0	15.1	12.9
9-12	12.0	13.7	3.0	2.0	2.7	1.2
12-15	13.0	11.3	0.1	2.3	0.6	0.2
15-18	14.1	10.1	-	0.6	0.3	0.1
18-21	15.8	5.4	-	-	0.7	0.1
21-24	11.6	1.2	-	0.1	0.4	-
24-27	6.3	0.3	-	-	-	-
27-30	0.5	0.1	-	-	-	-

of mean yearly entrainment over both daily and nighttime periods, larvae in smaller size classes represented a larger percentage of the total catch of all three species. The shift is especially evident for northern anchovy and white croaker. The trend toward overall higher percent abundance in smaller size classes is mainly a reflection of trends observed in night samples, when the majority of target species larvae are collected. Possible causes for the differences in abundances and the observed size-frequency shift include: 1) fewer anchovy and white croaker adults spawning in the area around San Onofre, either due to decreased abundance or a shift in location of major spawning grounds; 2) an increased mortality rate for northern anchovy and white croaker larvae over observations of the previous 18 months, whether due to increased predation, unfavorable water column conditions, or nutritional inadequacies; 3) an increase in the number of reproducing queenfish adults accompanied by an increase in queenfish larval mortality; and/or 4) an inshore shift of major queenfish spawning in the San Onofre area.

Factors Determining Entrainment Trends

Several factors combine to determine the abundance, composition, and size-frequency distribution of larvae entrained in offshore cooling water intakes. The composition of the larval assemblage is primarily dependent on habitat types near the intake, and the location of the riser in relation to the dominant water body available for entrainment (offshore pelagic, harbor, river, etc.). This factor is evidenced by the differences between intake species composition and abundance at Redondo Beach Units 5 and 6 compared to Units 7 and 8, located only 670 m apart. Species composition varies seasonally according to the life history of the various components of the assemblage, including preferred spawning season, spawning location (depth, temperature, etc.), and feeding mode of the larvae, which determine their vertical distribution (Schlotterbeck and Connally 1982).

Abundance of larvae in entrainment samples is highly dependent on the spawning success of individual species in the area of the intake, and may vary directly with distance of the intake from major spawning grounds, which will affect mortality and decrease the number of larvae available for entrainment. In

the immediate vicinity of the intake, physical characteristics of the intake itself, including flow volume, design of the riser structure, operating schedule of the plant, and location in the water column may be significant. The end result of these combined factors is the high degree of variability in plankton collections at all four sampled intakes.

Size-frequency distributions of individual species collected in entrainment samples are affected by timing and extent of vertical migration, ability to avoid the vicinity of the intake structure, and swimming ability of each species compared to intake flow rate. The absence of sciaenid larvae greater than 12 mm in entrainment samples from Redondo Beach Units 5 and 6 may be directly related to the low flow volume and intake velocity at this location. Other factors that determine size-frequency distributions are mortality rates among various size groups, and the distance that larvae must travel to be subject to entrainment, which will allow the larvae increased development time.

Influences of Physical Parameters

Tide. Tidal conditions in the vicinity of cooling water intakes may create turbulent flow conditions that affect larval distribution. Tidal height appeared to have a significant effect on larval entrainment only at one intake site. During four of the five months of highest entrainment levels at Ormond Beach (January through April 1980), the tide during the period of greatest larval entrainment was rising from a low to a high. The larval assemblage during each of these months was dominated by 316(b) target species that are pelagic spawners, especially northern anchovy and white croaker. At the other three intakes, periods of maximum larval loss during these same four months did not correlate well with tidal height, even at San Onofre, where larvae of 316(b) target species also dominated collections during months of peak abundance. While tidal influences and larval entrainment did not correlate well, the period displaying highest numbers of larvae entrained was most frequently in the crepuscular or nighttime hours. This indicates that while high or rising tides may influence entrainment of larvae spawned pelagically, the influence is coincidental with periods of transition of light and dark, when vertical migration (Sameoto 1975, Zaret and Suffern 1976) has been observed in many planktonic species and visual avoidance is reduced. Evidence of vertical migration by some 316(b) target species larvae has been discussed previously (SCE 1980). Vertical migration of target species larvae appears to be a more important factor than tidal level in determining levels of intake entrainment.

Sea State. The effects of storms and heavy swells have been shown to contribute to increased levels of impingement of adult fishes at coastal generating stations (SCE 1981). The influence of sea state on larval entrainment is less certain. At Ormond Beach, heavy seas were encountered during August 1979 and March and June 1980. As discussed previously, March entrainment concentrations were the highest observed at this intake. Total larval concentrations in August and June, however, ranked 11th and 12th, respectively, over the 12-month sampling year. Results at other intakes were similar to those observed at Ormond Beach. Total concentrations at San Onofre ranked 8th and 11th, respectively, during the months of observed heavy seas. Sea state, like tidal height, appears to be less of a factor determining larval entrainment than does vertical migration, visual avoidance, and seasonality.

Temperature-Salinity. At intakes drawing cooling water mainly from offshore areas, temperature and salinity appeared to have little effect on numbers of larvae entrained over a sampling day during any month. Relatively well-mixed water columns were observed during months of maximum entrainment with no thermocline or halocline discernable. During months when a distinct thermocline was

measured at one of the offshore intakes and high larval concentrations were observed, no consistent pattern of entrainment concentration versus thermocline location was noted. At Redondo Beach Units 5 and 6, highest larval entrainment was observed during summer months, when the water column in the harbor was well-stratified. The major thermal break in the water column temperature profile was observed below or at the level of the intake opening during these months. It is possible that larvae associated with the harbor and breakwater habitats migrate into the upper water column as the cooler salinity wedge enters the harbor during high tide, and are more susceptible to entrainment during this period.

The relationship between the temporal distribution of major target and non-target species and the physical environment was examined by graphical procedures. The mean surface and bottom water temperature and salinity observed during monthly intake collections were plotted together with the average number of daylight hours versus entrainment abundance. For the purpose of examination, larval species were divided into two groups: 1) species whose adults inhabit and spawn in the upper water column (northern anchovy); and 2) species whose adults inhabit and spawn in the lower water column or benthos (white croaker, queenfish, cheekspot goby, *Gibbonsia* sp. A and reef finspot). The occurrence and temporal distribution of individual species were then related to the temperatures and salinities corresponding to the adult habitat. The examination of the inter-relationship between the physical environment and cheekspot goby, reef finspot, and *Gibbonsia* sp. A was centered at Redondo Beach Units 5 and 6 because: 1) the species were more abundant at this intake than at the other sites; and 2) Redondo Beach Units 5 and 6 were not directly exposed to offshore waters, and thus the community was likely to be less affected by the surrounding waters than the remaining three sites.

Results of the examination revealed no relationship between the temporal distribution of selected species and salinity. General relationships were observed in several instances between species occurrence and temperature and/or photoperiod. Northern anchovy larvae exhibited no strict relationship with temperature or photoperiod, though the species was collected in higher densities in the "cold water" months of the year, following the summer temperature peak. A secondary peak in northern anchovy density corresponded to periods of annual maximum temperatures at offshore sites. The occurrence of white croaker corresponded to bottom water temperatures below 17°C at all but the San Onofre Unit 1 sampling site, where no relationship with temperature was observed. The initial appearance of the early developmental stages of white croaker (2.5 to 3 mm) corresponded to both decreased bottom temperature and photo-period at Ormond Beach and Redondo Beach Units 7 and 8.

METHODS

SAMPLING PROTOCOL

The monthly sampling regime at each intake was comprised of 24 half-hour pump samples, with four morning and four afternoon samplings during the day, and four evening and four pre-dawn samplings at night. Four half-hour samples were collected during both the sunrise and sunset crepuscular periods. The stations were sampled over a ten-day period near the middle of each month, with sampling coordinated in time with offshore collections by USC's IMCS effort. Typically, San Onofre Unit 1 was sampled on a Wednesday, Ormond Beach the following Monday, and the two Redondo Beach study locations were sampled concurrently the following Thursday. The initial period sampled was the morning (0900-1100 PST, 4 replicates), and the final period was sunrise the following day.

Sample volume need be sufficiently large to collect adequate numbers of target species for reliable statistical treatment; however, increased volume over time may induce higher sampling mortality (McGroddy and Wyman 1977). Temporal differences in concentrations potentially require differential volumes. Results of ichthyoplankton collection at the SONGS Unit 1 intake from August 1977 to July 1979 (SCE 1980) indicated volumes of 100 m^3 were required to accurately estimate target species concentrations. Volumes for entrainment inventory (and subsequent mass balance) samples were $100 \pm 10 \text{ m}^3$.

Analyses of ichthyoplankton concentrations over 24 months at SONGS Unit 1 intake (SCE 1980) showed that data variability of target species (*E. mordax*, *G. lineatus*, and *S. politus*) was sufficiently high that sampling need be conducted at least monthly to detect species differences of 100 to 150% among months. Those studies also demonstrated that a wide fluctuation in replication was required to detect differences between the means of any two replicates (50 to 300%), and that replication is dependent on target species, time of day, and season. When sampling was conducted during moderate concentrations (500 to 5000/1000 m^3) of target species (February to May), 24 intake replicates were determined satisfactory to detect a 50 to 200% difference between any two replicates.

Samples of entrained ichthyoplankton were pumped from within the intake risers using a centrifugal whorl Nielsen Model NCH Fish Pump rated at $227 \text{ m}^3 \text{ hr}^{-1}$ at 2 m head. The pump discharge was directed over the side of the vessel and was equipped with a Dacron sleeve which increased from 25.4 cm diameter at the pump discharge terminus to 1 m diameter at the point of attachment to the filtering net.

The filtering ratio, or filtering area to mouth area, was designed to meet the special requirements of the fish pump net. A theoretical ratio, R, was calculated from a desired collection volume and the fixed mouth area. The theoretical R or filtering ratio was calculated as:

$$\log_{10} R = .38 \log_{10} \frac{V}{A} -.17$$

where V was volume filtered and A was mouth area. This equation, from Smith et al. (1968), was for nearshore or "green water", where clogging was less likely. Calculations were based on a porosity of 0.46 associated with 333 micron Nitex mesh. Since the actual R (filtering area/mouth area), equals the theoretical R, nearshore net clogging was rarely expected. The actual R (filtering area/mouth area) of the fish pump net was 4.26, with a total mesh area of 7.32 m^2 . The cylinder and cone areas were 4.38 m^2 and 2.93 m^2 , respectively.

Intake samples were filtered through a 333 micron mesh net and preserved with 4% buffered Formalin-seawater. Volumes of water pumped were estimated using a General Oceanics Model 2030 flowmeter mounted in the aluminum intake elbow.

LABORATORY PROCESSING

Intake and discharge samples were sorted in the laboratory using dissecting microscopes. No reduction in sample size was made at any time. All samples were resorted with the final resort recovery rate greater than 99%.

General processing procedures were a modification of Smith and Richardson (1977), and permanent fixation followed Ahlstrom (1976). All larvae were sorted, identified to the lowest possible taxon, and enumerated. Key species were measured to the nearest 0.5 mm.

ESTIMATE OF LARVAL ENTRAINMENT

Empirical data from intake samples were used to estimate the annual loss attributable to entrainment. Entrainment estimates were based on the following assumptions: 1) a representative sample was withdrawn from the intake; 2) the density and composition of samples collected during the 12 monthly surveys were representative of unsampled periods; and 3) the cooling water volume circulated per unit time was consistent and continuous over one year.

The daily loss, in numbers of individuals for each species, was calculated as:

$$(1) \quad \text{Daily Loss} = [\text{Volume circulated/day}] [(\text{density}_{\text{day}})(\text{day hours}/24 \text{ hours}) + (\text{density}_{\text{sunset}})(\text{sunset hours}/24 \text{ hours}) + (\text{density}_{\text{night}})(\text{night hours}/24 \text{ hours}) + (\text{density}_{\text{sunrise}})(\text{sunrise hours}/24 \text{ hours})]/1000\text{m}^3$$

where density = mean number 1000 m⁻³ collected during a sample period.

The monthly loss, in numbers of individuals for each species was calculated as:

$$(2) \quad \text{Monthly loss} = (\text{Daily loss}) (D_m)$$

daily loss = from equation (1)
 D_m = 50% of the days until the subsequent survey
 + 50% of the days from the previous survey

The annual loss, in numbers of individuals for each species was calculated as:

$$(3) \quad \text{Annual Loss} = \text{month}_1 + \text{month}_2 \dots \text{month}_{12}$$

Monthly loss = from equation (2).

DETAILED RESULTS AND ANALYSES

At Ormond Beach, five taxa comprised 80% of the catch during 10 of the 12 months sampled, while at Redondo Beach Units 5 and 6, five taxa comprised 80% of the catch during 9 of the 12 months sampled. Although the dominance of the major taxa at San Onofre Unit 1 and Redondo Beach Units 7 and 8 was not as extensive, the five major species still comprised over 60% of the catch for the majority of the year.

Overall, intake concentrations at Redondo Beach Units 7 and 8 were the highest observed during 5 of the 12 survey months, including summer, fall, winter, and spring sampling periods, attesting to the diverse assemblage of species affected by this intake. Major periods of entrainment at Redondo Beach Units 7 and 8 were from December to March and June to September, and total numbers of species collected each month were the highest of all four intakes sampled. Numbers of 316(b) target species and maximum numbers of species collected in a single replicate sample were consistently among the highest observed each month.

Samples collected at Ormond Beach Generating Station also comprised a major portion of overall larval entrainment. The sandy bottom habitat surrounding the intake resulted in pelagic and soft bottom species dominating the collected larval assemblage. Larval concentrations at Ormond Beach were highest among the four intakes during four months, all occurring between November 1979 and May 1980, indicating the influence of winter spawning species. Occurrence of highest larval concentrations during these months was consistently observed during crepuscular periods, while occurrences of highest concentrations during other

months was variable. Numbers of 316(b) target species observed and maximum numbers of species taken in a single replicate were only slightly lower than those observed at Redondo Beach Units 7 and 8.

Entrainment levels at San Onofre Unit 1 during the 316(b) study program were lower than those observed during the previous PMP study, August 1977 to July 1979 (SCE 1980). Due to the variety of habitats in the vicinity of the intake (kelp, sand, cobble, and reef), the most frequently collected species were from pelagic, kelp, and soft bottom habitats. In none of the 12 sampling months were concentrations the highest among the four sampled intakes; however, peaks in abundances at San Onofre coincided with peaks at other intakes. The major entrainment period at San Onofre occurred between March and May, with a secondary peak during September and October. Total numbers of species collected monthly were high in August and September 1979, but thereafter were consistently the lowest among the four intakes, a trend also noted for both numbers of 316(b) target species collected monthly and maximum numbers of species in any one replicate. The sampling period during which highest numbers of larvae were collected was variable from month to month, although during months of highest entrainment the majority of larvae were taken between evening and sunrise periods.

The composition of the larval assemblage at Redondo Beach Units 5 and 6 was substantially different from that of the other three intakes, as the main influence on entrainment composition was the soft bottom-reef community associated with the breakwater and harbor surrounding the intake location. As a result, 316(b) target species comprised a relatively small portion of total larval entrainment compared to the other study areas. Larval concentrations observed at Units 5 and 6 were the highest among the four intakes during 3 of the 12 months sampled. Each peak occurred during summer or early fall months, which comprised the major entrainment period at this intake. While the total number of species collected at Units 5 and 6 was higher than at San Onofre, the number of target species observed and the maximum numbers of species taken in any one replicate were the lowest among the four study sites. The majority of larvae collected at this intake were generally taken during crepuscular and nighttime periods, with highest concentrations observed during the morning period on only one occasion.

ENTRAINMENT SPECIES COMPOSITION

Northern anchovy was the dominant species of ichthyoplankton at San Onofre Unit 1 and Ormond Beach, and the second most abundant species collected at Redondo Beach Units 7 and 8 (Tables 7, 8, and 9). The temporal distribution of the species varied between sampling sites. At San Onofre Unit 1, major increases were observed during September and October and again from February through May. At Redondo Beach Units 7 and 8, concentrations of northern anchovy peaked in January and March, with a minor increase recorded in September, while at Ormond Beach maximum concentrations were observed in February and March (Figures 8, 9, and 10).

White croaker was the second most abundantly collected larva. White croaker was the most abundant larvae entrained at Redondo Beach Units 7 and 8 and ranked second at San Onofre Unit 1 and Ormond Beach (Tables 9, 7, and 8, respectively). The temporal distribution of white croaker also varied between sampling sites. Population densities substantially increased at all sampling sites during February and/or March, as well as major increases during January at Redondo Beach Units 7 and 8 and during December and May at San Onofre Unit 1 (Figures 8 and 9).

Queenfish, though generally not as abundant as northern anchovy or white croaker, was still a major component of the ichthyoplankton community at all but Redondo Beach Units 5 and 6 (Table 10; Figure 11). At the remaining three

Table 7. Annual estimated number of larvae entrained by San Onofre Unit 1 based on mean and median concentrations.

Species	Common Name	Total From Mean (x10 ⁶)	Rank	% Total	Total From Median (x10 ⁶)	Rank	Total
TOTAL LARVAE		690.7		100.0	622.0		100.0
<u>Engraulis mordax</u> *	northern anchovy	312.3	1	45.2	305.6	1	49.1
<u>Seriphus politus</u> *	queenfish	72.1	2	10.4	58.5	3	9.4
<u>Genyonemus lineatus</u> *	white croaker	70.1	3	10.1	61.9	2	10.0
<u>Pisces</u> yolk sac larvae	yolk sac larvae	45.8	4	6.6	39.9	4	6.4
<u>Ilypnus gilberti</u>	cheekspot goby	37.1	5	5.4	37.1	5	6.0
<u>Lepidogobius lepidus</u>	bay goby	29.3	6	4.2	28.5	6	4.6
<u>Hypsoblennius</u> spp.	blenny	27.9	7	4.0	21.4	7	3.4
<u>Menticirrhus undulatus</u>	California corbina	15.7	8	2.3	13.5	8	2.2
<u>Gibbonia</u> sp. A	kelpfish	11.1	9	1.6	9.2	9	1.5
<u>Pisces</u> larvae unid.	fragments and mutilated	10.8	10	1.6	7.5	12	1.2
<u>Atherinopsis californiensis</u>	jacksmelt	10.0	11	1.5	8.1	11	1.3
<u>Roncador stearnsii</u> *	spotfin croaker	8.0	12	1.2	8.2	10	1.3
<u>Gobiosox rhessodon</u>	California clingfish	7.4	13	1.1	5.3	13	0.9
<u>Typhlogobius californiensis</u>	blind goby	6.0	14	0.9	2.4	16	0.4
<u>Paralichthys californicus</u> / <u>Xysteuropsis</u> <u>luteus</u>	California halibut/ fantail sole	5.9	15	0.9	4.2	14	0.7
<u>Citharichthys</u> spp.	sanddab	3.4	16	0.5	2.8	15	0.5
<u>Hypsopsetta guttulata</u>	diamond turbot	2.9	17	0.4	2.2	17	0.4
<u>Triphoturus mexicanus</u>	Mexican lampfish	2.3	18	0.3	1.3	19	0.2
<u>Gobiidae</u> unid.	goby	2.2	19	0.3	1.4	18	0.2
<u>Heterostichus rostratus</u>	giant kelpfish	2.1	20	0.3	1.0	20	0.2
<u>Paralabrax clathratus</u> *	kelp bass	2.1	21	0.3	0.9	21	0.1
<u>Cheilodroma saturnum</u> *	black croaker	0.8	23	0.1	0.1	26	<0.1
<u>Peprilus similimus</u> *	Pacific butterfish	0.5	25	0.1	0.2	25	<0.1
<u>Anisotremus davidsoni</u> *	sargo	0.4	27	0.1	-	-	-
<u>Paralabrax nebulifer</u> *	barred sand bass	<0.1	66	<0.1	-	-	-
<u>Sebastes paucispinis</u> *	bocaccio	-	-	-	-	-	-
<u>Umbrina roncadore</u> *	yellowfin croaker	-	-	-	-	-	-
				99.4			99.9

*316(b) target species

Table 8. Annual estimated number of larvae entrained by Ormond Beach based on mean and median concentrations.

Species	Common Name	Total From Mean (x10 ⁶)	Rank	% Total	Total From Median (x10 ⁶)	Rank	Total
TOTAL LARVAE		2,151.2		100.0	1,885.9		100.0
<u>Engraulis mordax</u> *	northern anchovy	900.1	1	41.8	834.3	1	44.2
<u>Genyonemus lineatus</u> *	white croaker	727.4	2	33.8	658.3	2	34.9
<u>Seriphus politus</u> *	queenfish	176.8	3	8.2	142.4	3	7.6
<u>Pisces</u> larvae unid.	fragments and mutilated	117.8	4	5.5	76.1	4	4.0
<u>Lepidogobius lepidus</u>	bay goby	66.5	5	3.1	62.9	5	3.3
<u>Pisces</u> yolk sac larvae	yolk sac larvae	45.7	6	2.1	35.3	6	1.9
<u>Ilypnus gilberti</u>	cheekspot goby	42.0	7	2.0	32.8	7	1.7
<u>Gobiidae</u> type D	goby	14.3	8	0.7	9.0	8	0.5
<u>Gobiidae</u> unid.	goby	11.0	9	0.5	7.5	9	0.4
<u>Paralichthys californicus</u> / <u>Xysteuropsis</u> <u>luteus</u>	California halibut/ fantail sole	5.9	10	0.3	4.0	10	0.2
<u>Citharichthys</u> spp.	sanddab	4.5	11	0.2	3.4	11	0.2
<u>Stenobrachius leucopsarus</u>	northern lampfish	4.2	12	0.2	1.9	13	0.1
<u>Synodus lucioceps</u>	California lizardfish	3.5	13	0.2	0	20	0.0
<u>Hypsoblennius</u> spp.	blenny	3.5	14	0.2	2.9	12	0.2
<u>Hypsopsetta guttulata</u>	diamond turbot	3.2	15	0.2	1.9	15	0.1
<u>Gillichthys mirabilis</u>	long jaw mudsucker	2.5	16	0.1	0.5	19	0.0
<u>Otophidium scrippsii</u>	basketweave cusk eel	2.2	17	0.1	1.5	16	0.1
<u>Sardinops sagax caeruleus</u>	Pacific sardine	2.1	18	0.1	1.5	18	0.1
<u>Paralabrax clathratus</u> *	kelp bass	2.1	19	0.1	1.5	17	0.1
<u>Paralabrax nebulifer</u> *	barred sand bass	1.8	20	0.1	1.9	14	0.1
<u>Peprilus similimus</u> *	Pacific butterfish	1.2	22	0.1	0.6	21	<0.1
<u>Cheilodroma saturnum</u> *	black croaker	0.3	37	<0.1	-	-	-
<u>Umbrina roncadore</u> *	yellowfin croaker	0.1	42	<0.1	-	-	-
<u>Anisotremus davidsoni</u> *	sargo	0.1	47	<0.1	-	-	-
<u>Roncador stearnsii</u> *	spotfin croaker	-	-	-	-	-	-
<u>Sebastes paucispinis</u> *	bocaccio	-	-	-	-	-	-
				99.6			99.7

* 316(b) target species

Table 9. Annual estimated number of larvae entrained by Redondo Beach Units 7 & 8 based on mean and median concentrations.

Species	Common Name	Total From Mean (x10 ⁶)	Rank	% Total	Total From Median (x10 ⁶)	Rank	% Total
TOTAL LARVAE		2,971.7		100.0	2,485.6		100.0
<u>Genyonemus lineatus*</u>	white croaker	1,197.0	1	40.3	1,096.0	1	44.1
<u>Engraulis mordax*</u>	northern anchovy	428.7	2	14.4	380.2	2	15.3
<u>Ilypnus gilberti</u>	cheekspot goby	199.0	3	6.7	170.9	3	6.9
<u>Seriphus politus*</u>	queenfish	185.3	4	6.2	145.4	4	5.8
<u>Pisces yolk sac larvae</u>	yolk sac larvae	135.6	5	4.6	115.8	6	4.7
<u>Paraclinus integripinnis</u>	reef finspot	128.1	6	4.3	121.4	5	4.9
<u>Gibbonsia sp. A</u>	kelpfish	119.4	7	4.0	100.1	7	4.0
<u>Hypsoblennius spp.</u>	blenny	113.5	8	3.8	82.2	8	3.3
<u>Chromis punctipinnis</u>	blacksmith	91.6	9	3.1	4.2	20	0.2
<u>Pisces larvae unid.</u>	fragments and mutilated	83.1	10	2.8	67.2	9	2.7
<u>Paralichthys californicus/</u>	California halibut/						
<u>Xystreurus tirolepis</u>	fantail sole	57.6	11	1.9	43.2	11	1.7
<u>Gobiesox rhessodon</u>	California clingfish	45.1	12	1.5	44.1	10	1.8
<u>Gobiidae type D</u>	goby	39.8	13	1.3	24.2	12	1.0
<u>Clinidae unid.</u>	clinid	15.3	14	0.5	8.3	16	0.3
<u>Sardinops sagax caeruleus</u>	Pacific sardine	14.7	15	0.5	12.2	13	0.5
<u>Gobiidae unid.</u>	goby	13.0	16	0.4	8.8	15	0.4
<u>Lythrypnus sp.</u>	goby	11.6	17	0.4	9.3	14	0.4
<u>Cottidae type 7</u>	sculpin	8.4	18	0.3	7.1	18	0.3
<u>Hypsopsetta guttulata</u>	diamond turbot	7.9	19	0.3	8.1	17	0.3
<u>Pleuronichthys verticalis</u>	hornyhead turbot	6.9	20	0.2	5.1	19	0.2
<u>Paralabrax clathratus*</u>	kelp bass	2.0	36	0.1	0.8	32	<0.1
<u>Peprilus simillimus*</u>	Pacific butterfish	0.9	40	<0.1	0.7	33	<0.1
<u>Anisotremus davidsoni*</u>	sargo	0.6	44	<0.1	0.1	42	<0.1
<u>Paralabrax nebulifer*</u>	barred sandbass	0.5	48	<0.1	-	-	-
<u>Chelotrema saturnum*</u>	black croaker	0.3	55	<0.1	0.2	41	<0.1
<u>Roncador stearnsii*</u>	spotfin croaker	-	-	-	-	-	-
<u>Sebastes paucispinnis*</u>	bocaccio	-	-	-	-	-	-
<u>Umbrina roncadore*</u>	yellowfin croaker	-	-	-	-	-	-
				97.6			98.8

* 316(b) target species

sites, queenfish was present in samples from August through October and again from March through July. Overall queenfish entrainment decreased in density from south to north within the study area. At San Onofre Unit 1, queenfish maximum density was recorded in May with a minor peak in September, while at Redondo Beach Units 7 & 8 the species reached maximum density during March (Figures 8 and 9). Concentrations remained relatively low during the period March through June at Ormond Beach, followed by increases in July and September (Figure 10).

Of the remaining 316(b) key species, only spotfin croaker, Roncador stearnsii, contributed appreciably to entrainment collections at any of the four sampled sites. The species was collected only during September 1979 at San Onofre Unit 1, when it represented approximately 10% of the total catch. Adult spotfin are frequently taken in SONGS impingement collections, but are rarely observed at other stations. The remaining target species, with the exception of bocaccio, Sebastes paucispinnis, were collected at three or more of the sampling sites, although they were uncommon or rare. Bocaccio, one of the few species of Sebastes identifiable in larval form, was not collected.

Three major groups other than the target species contributed significantly to the ichthyoplankton community entrained at one or more study sites. The three groups were gobies, clinids, and blennies.

The most commonly entrained goby larva, I. gilberti (cheekspot goby), was taken regularly at all intakes, with maximum densities recorded from June through December to February, depending on the sampling site. The species was among the top five taxa entrained at each sampling site, though only at Redondo Beach Units 5 & 6 did it comprise a major fraction of entrainment samples for any extended period of time (Figure 12).

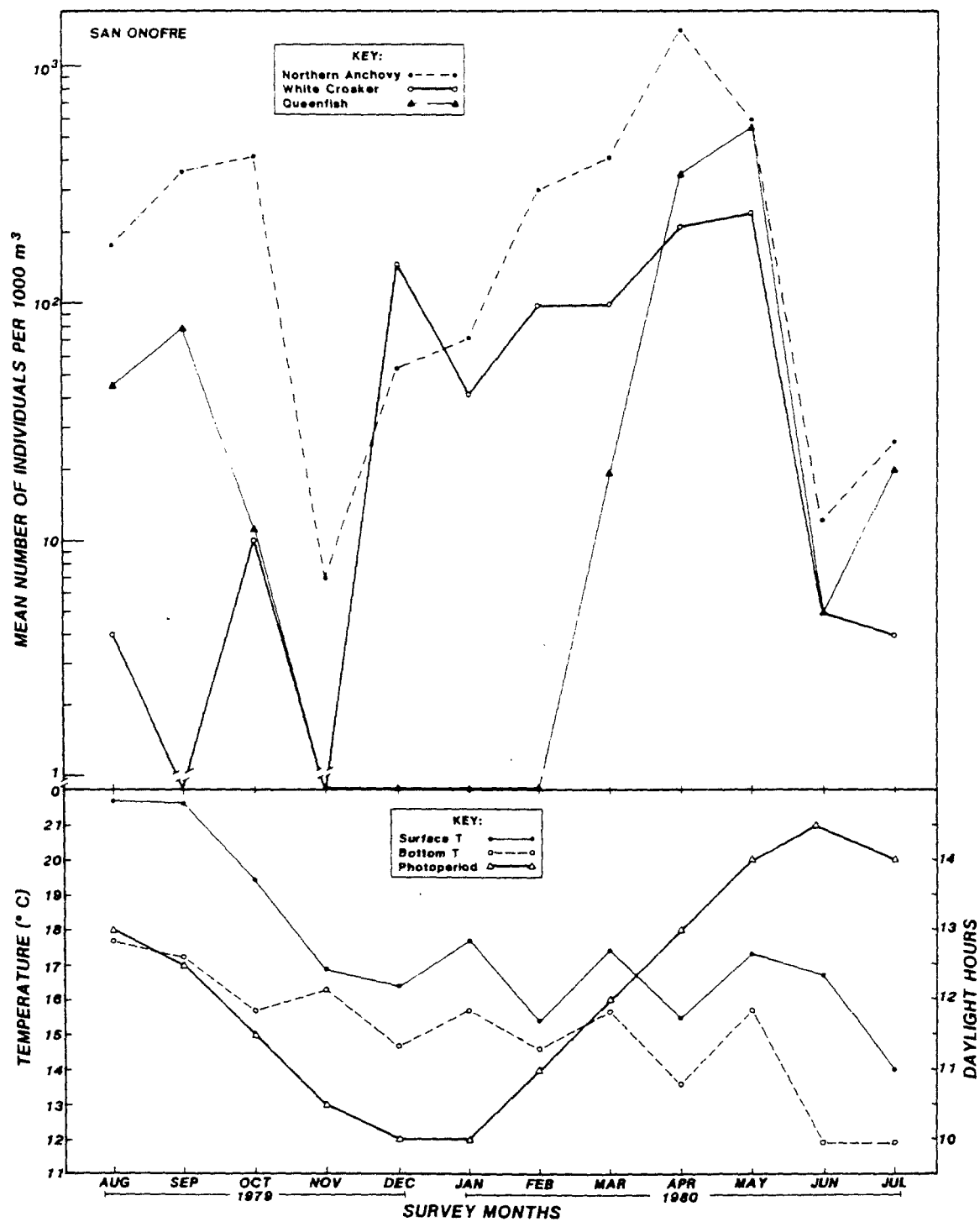


Figure 8. Monthly concentrations of three target species in entrainment samples from San Onofre Unit 1, and behavior of environmental variables during the same period.

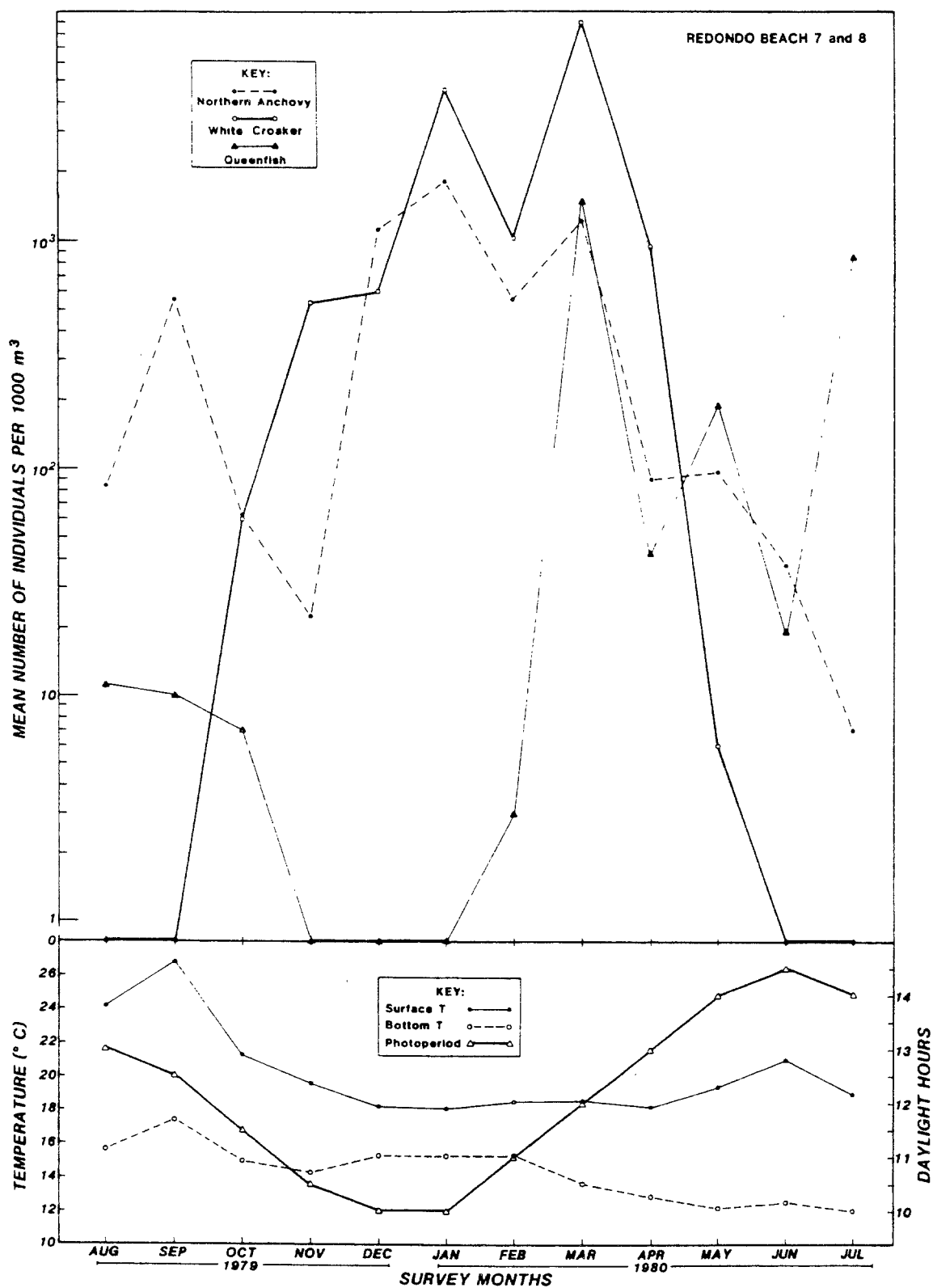


Figure 9. Monthly concentrations of three target species in entrainment samples from Redondo Beach Units 7 and 8, and behavior of environmental variables during the same period.

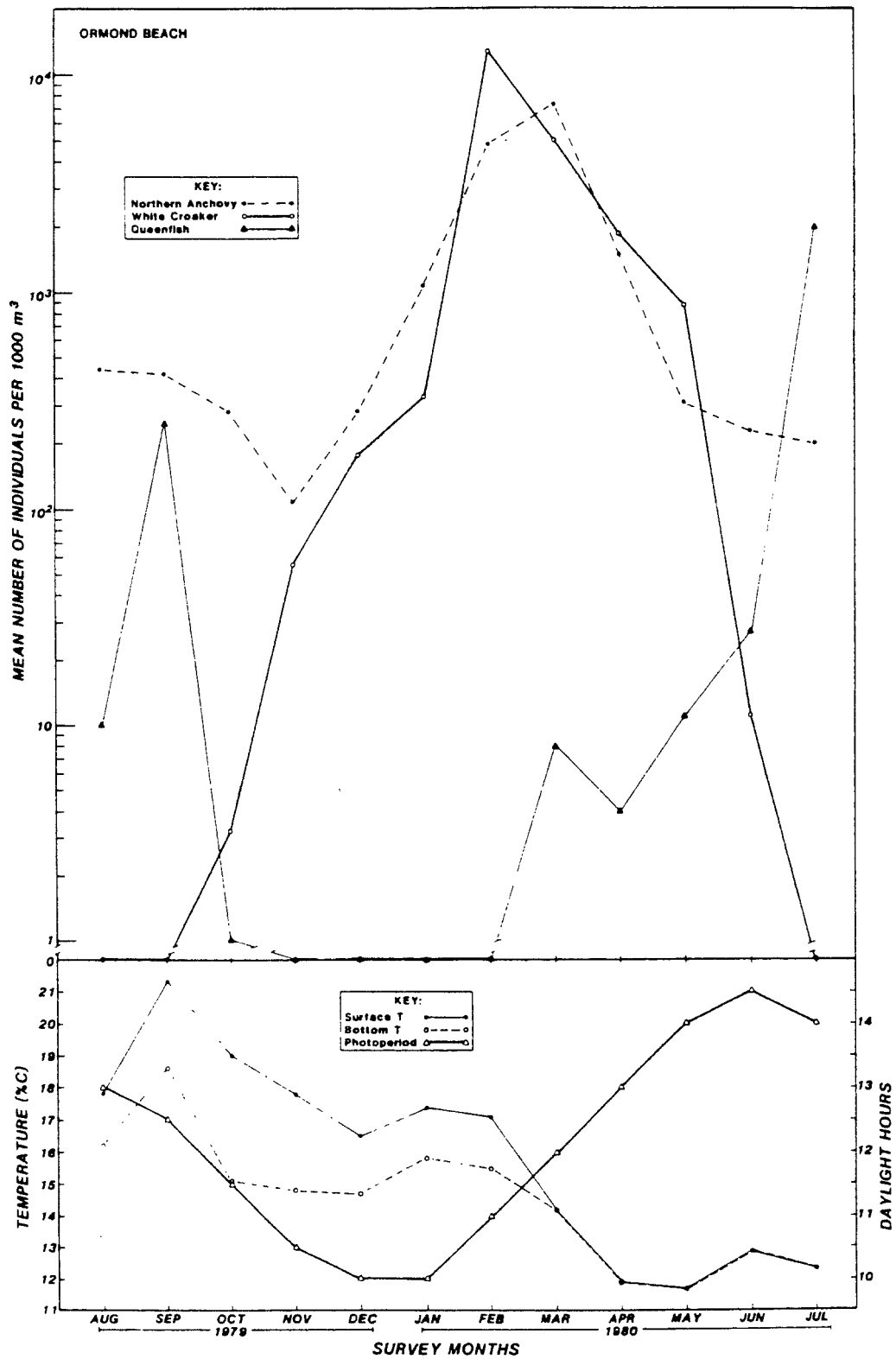


Figure 10. Monthly concentrations of three target species in entrainment samples from Ormond Beach, and behavior of environmental variables during the same period.

Table 10. Annual estimated number of larvae entrained by Redondo Beach Units 5 & 6 based on mean and median concentrations.

Species	Common Name	Total From Mean (x10 ⁶)	Rank	% Total	Total From Median (x10 ⁶)	Rank	% Total
TOTAL LARVAE		395.5		100.0	302.7		100.0
<i>Ilypnus gilberti</i>	cheekspot goby	128.2	1	32.4	108.5	1	35.8
<i>Paraclinus integripinnis</i>	reef finspot	96.7	2	24.5	63.2	2	20.9
<i>Gibbonsia</i> sp. A	kelpfish	71.0	3	18.0	51.6	3	17.0
<i>Genyonemus lineatus</i> *	white croaker	33.2	4	8.4	31.6	4	10.4
<i>Hypsoblennius</i> spp.	blenny	25.5	5	6.5	22.2	5	7.3
Pisces larvae unid.	fragments and mutilated	9.4	6	2.4	6.7	6	2.2
Gobiidae unid.	goby	5.2	7	1.3	2.8	8	0.9
<i>Gobiosox rhessodon</i>	California clingfish	3.3	8	0.8	2.8	7	0.9
Pisces yolk sac larvae	yolk sac larvae	3.0	9	0.8	2.6	9	0.9
<i>Heterostichus rostratus</i>	giant kelpfish	2.6	10	0.7	1.9	10	0.6
<i>Lythrypnus</i> sp.	goby	2.3	11	0.6	1.4	12	0.5
<i>Engraulis mordax</i> *	northern anchovy	2.3	12	0.6	1.6	11	0.5
Clinidae unid.	clinid	2.1	13	0.5	0.9	15	0.3
<i>Lepidogobius lepidus</i>	bay goby	1.7	14	0.4	0.8	16	0.3
<i>Hypsypops rubicunda</i>	garibaldi	1.4	15	0.4	0.9	14	0.3
<i>Seriophilus politus</i> *	queenfish	1.2	16	0.3	1.0	13	0.3
Cottidae type 2	sculpin	1.2	17	0.3	0.3	20	0.0
Gobiidae type D	goby	0.8	18	0.2	0.2	19	0.1
<i>Quiatula y-cauda</i>	shadow goby	0.7	19	0.2	0.3	17	0.1
<i>Typhlogobius californiensis</i>	blind goby	0.5	20	0.1	0.2	18	0.1
<i>Paralabrax clathratus</i> *	kelp bass	0.2	27	<0.1	0.2	21	0.1
<i>Cheilodroma saturnum</i> *	black croaker	<0.1	55	<0.1	-	-	-
<i>Peprilus simillimus</i> *	Pacific butterfish	<0.1	58	<0.1	-	-	-
<i>Anisotremus davidsoni</i> *	sargo	<0.1	62	<0.1	-	-	-
<i>Paralabrax nebulifer</i> *	barred sand bass	-	-	-	-	-	-
<i>Roncadora stearnsi</i> *	spotfin croaker	-	-	-	-	-	-
<i>Sebastes paucispinis</i> *	bocaccio	-	-	-	-	-	-
<i>Umbrina roncadora</i> *	yellowfin croaker	-	-	-	-	-	-
				99.2			99.5

* 316(b) target species

The bay goby, *Lepidogobius lepidus*, was a common component of the ichthyoplankton community at both San Onofre Unit 1 and Ormond Beach (Figures 13 and 14), where it comprised approximately 2% of annual larval entrainment. The was present during all months (except November at San Onofre), with maximum densities recorded between September and January. Entrainment densities may have been underestimated because it was taxonomically separated from Gobiidae type D, which may be an early developmental stage of the bay goby.

Clinids were seasonally common members of the ichthyoplankton at all stations except Ormond Beach. The two major species of clinids collected were *Gibbonsia* sp. A (probably spotted kelpfish, *G. elegans*) and reef finspot, *Paraclinus integripinnis*. *Gibbonsia* sp. A was the only clinid entrained in significant concentrations at San Onofre Unit 1, where it comprised from 3 to 12% of the entrained ichthyoplankton between October and February.

Gibbonsia sp. A was one of the more common larval fish present at Redondo Beach, representing approximately 4 and 19% of the entrained larvae annually at Redondo Beach Units 7 and 8 and Units 5 and 6, respectively. Peak densities were reached during the fall and early winter months.

Reef finspot was also a major component of the entrained ichthyoplankton community at Redondo Beach (Figures 12 and 15), particularly at Units 5 and 6, where it accounted for 26% of the larvae entrained annually. The species was especially abundant in June and July, when it comprised from 17 to 54% of the entrained larvae (Figure 12).

The blennies, represented by the taxa *Hypsoblennius* spp. were the third non-target species group commonly entrained. *Hypsoblennius* annually comprised

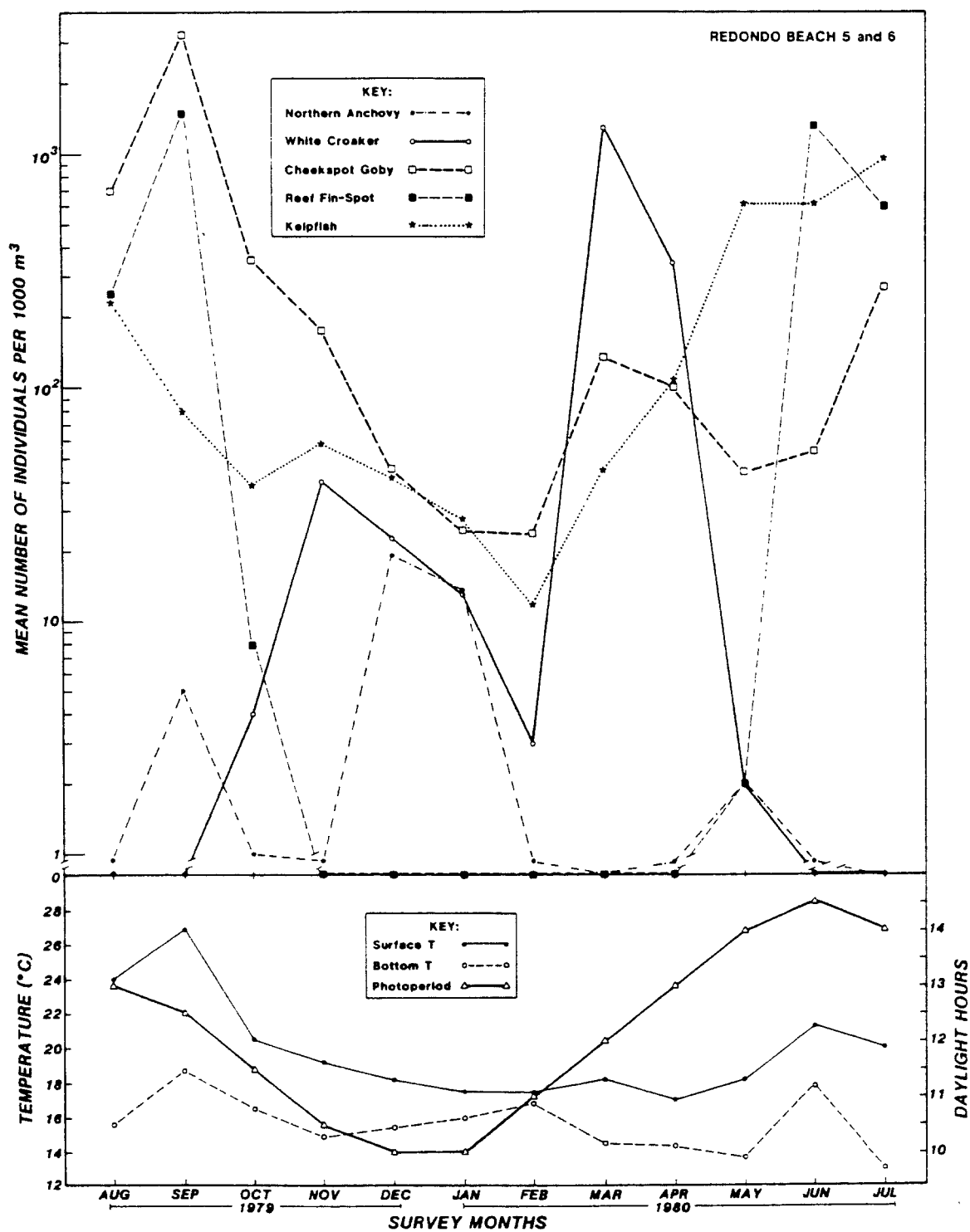


Figure 11. Monthly concentrations of several target and non-target species in entrainment samples from Redondo Beach Units 5 and 6, and behavior of environmental variables during the same periods.

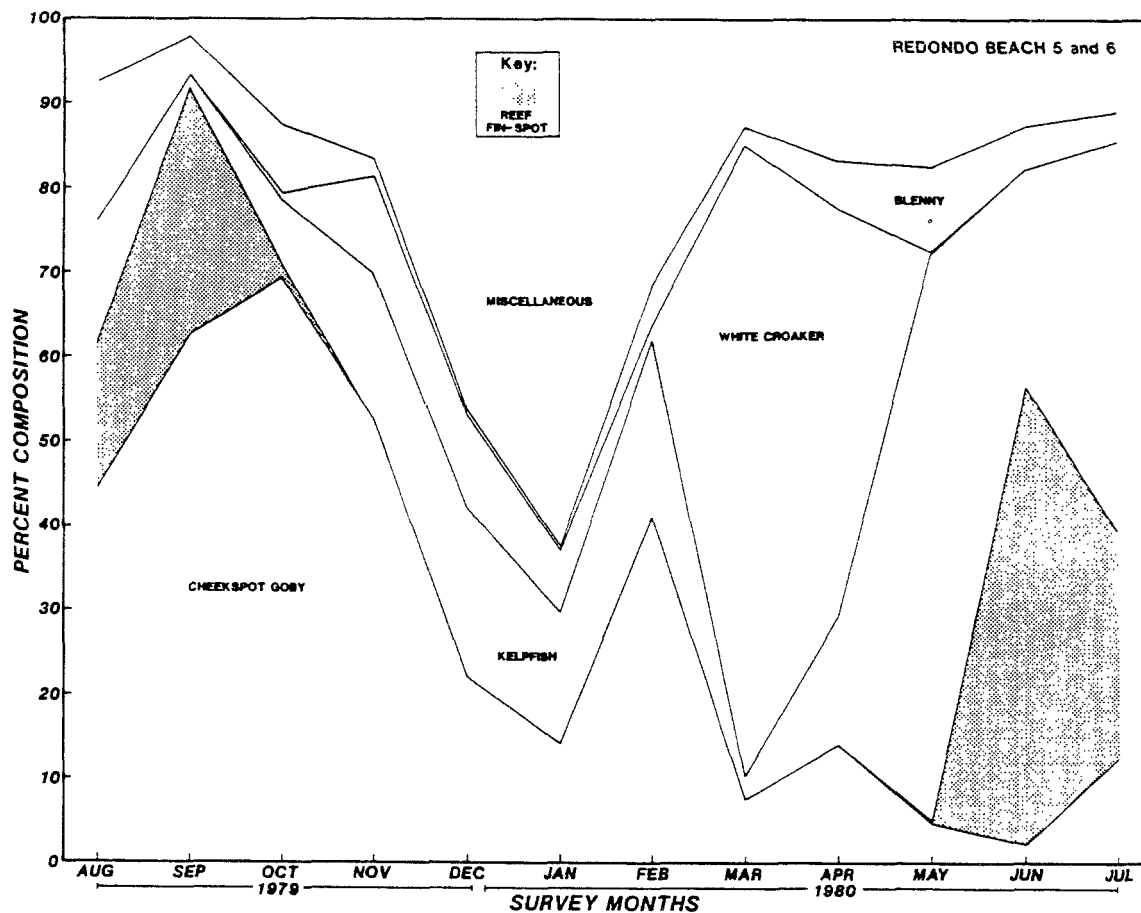


Figure 12. Monthly percent composition of abundant entrained larvae at Redondo Beach Units 5 and 6.

approximately 3% of the larvae entrained at San Onofre Unit 1 (Figure 13) and Redondo Beach Units 7 and 8, and 7% at Redondo Beach Units 5 and 6. This group was present during each monthly sampling period with maximum concentrations recorded during July through December.

As was anticipated, three species (northern anchovy, white croaker, and queenfish) generally dominated the larval assemblage entrained at all sampling sites except Redondo Beach Units 5 and 6. The adults of white croaker and queenfish are abundant demersal species occurring in the shallow, sandy bottom areas adjacent to the sampling sites (MBC 1979a,b; SCE 1979a), while the adults of northern anchovy are one of the major pelagic fish occurring in the California Current system.

White croaker was a major component of the ichthyoplankton community entrained at Redondo Beach Units 5 and 6 (Figure 12), while the larvae of queenfish and northern anchovy represented minor elements. Low concentrations of entrained northern anchovy and queenfish larvae are partially related to offshore spawning (Ahlstrom 1956, SCE 1979a, Watson 1979). Larvae of northern anchovy and queenfish must be transported by the prevailing currents into the harbor before entrainment is possible. In contrast, white croaker is an inshore spawner and the center of the larval population is located closer to the Redondo Beach Units 5 and 6 intake.

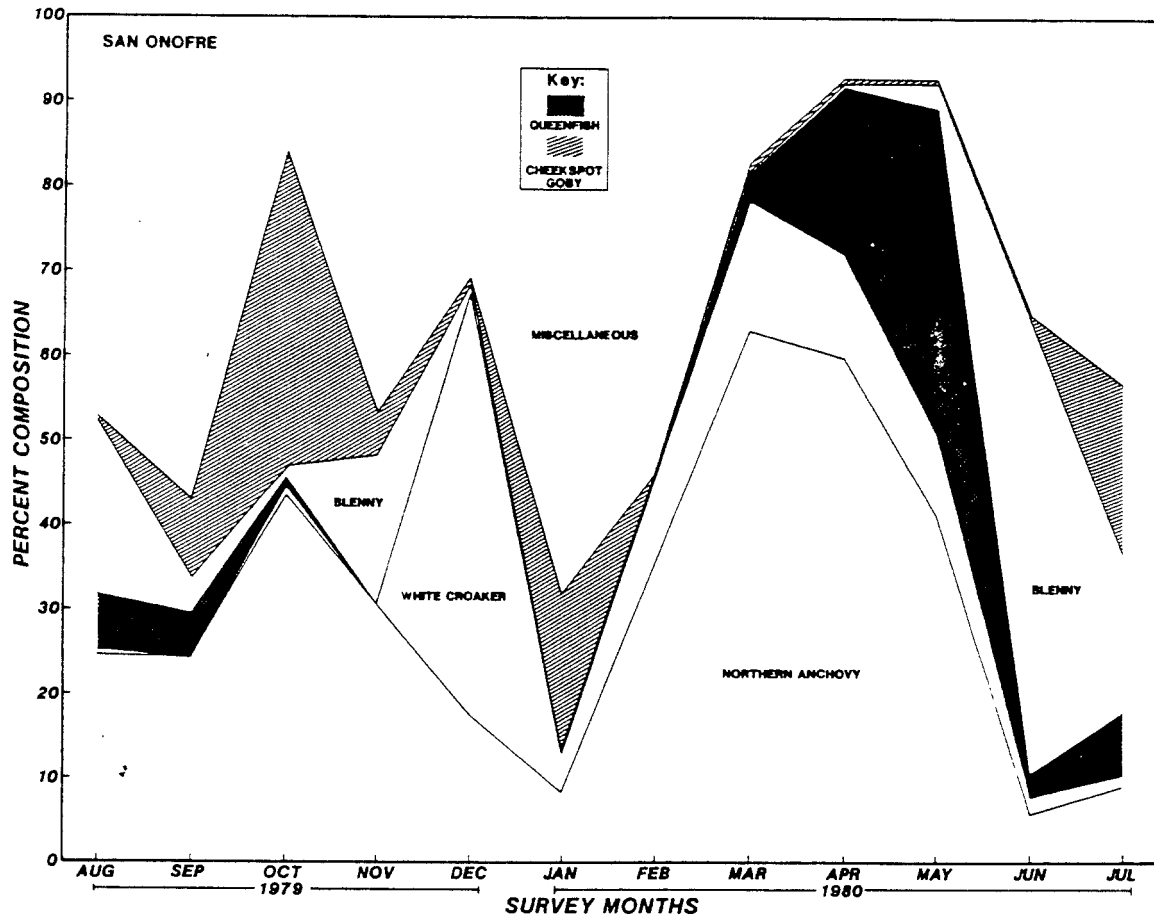


Figure 13. Monthly percent composition of abundant entrained larvae at San Onofre Unit 1.

SIZE FREQUENCY DISTRIBUTION OF ENTRAINED TARGET SPECIES

All larvae of 316(b) target and key species were measured concurrent with identification. Size frequency distributions of target larvae were examined for prevalence of entrainment of certain size classes during sampling months or seasonal periods. Comparisons are restricted to larvae of northern anchovy, white croaker, and queenfish, as other target species occurred too sporadically for meaningful analysis.

Northern Anchovy

Northern anchovy was the only target species collected during all 12 months of the 316(b) ichthyoplankton program, and was absent from each of two intakes during only one month. The size frequency distribution of samples of entrained larvae was dependent on the spawning condition of the adult population and the time of sampling. Occurrence of northern anchovy at Redondo Beach Units 5 and 6 was sporadic, and larvae were collected in all six daily sampling periods during only two months. At the remaining three intakes, the median size of entrained larvae generally increased at or after sunset, and often continued to increase through the sunrise sampling period. This trend was most pronounced in months when low numbers of larvae occurred (indicating that the adult population had not

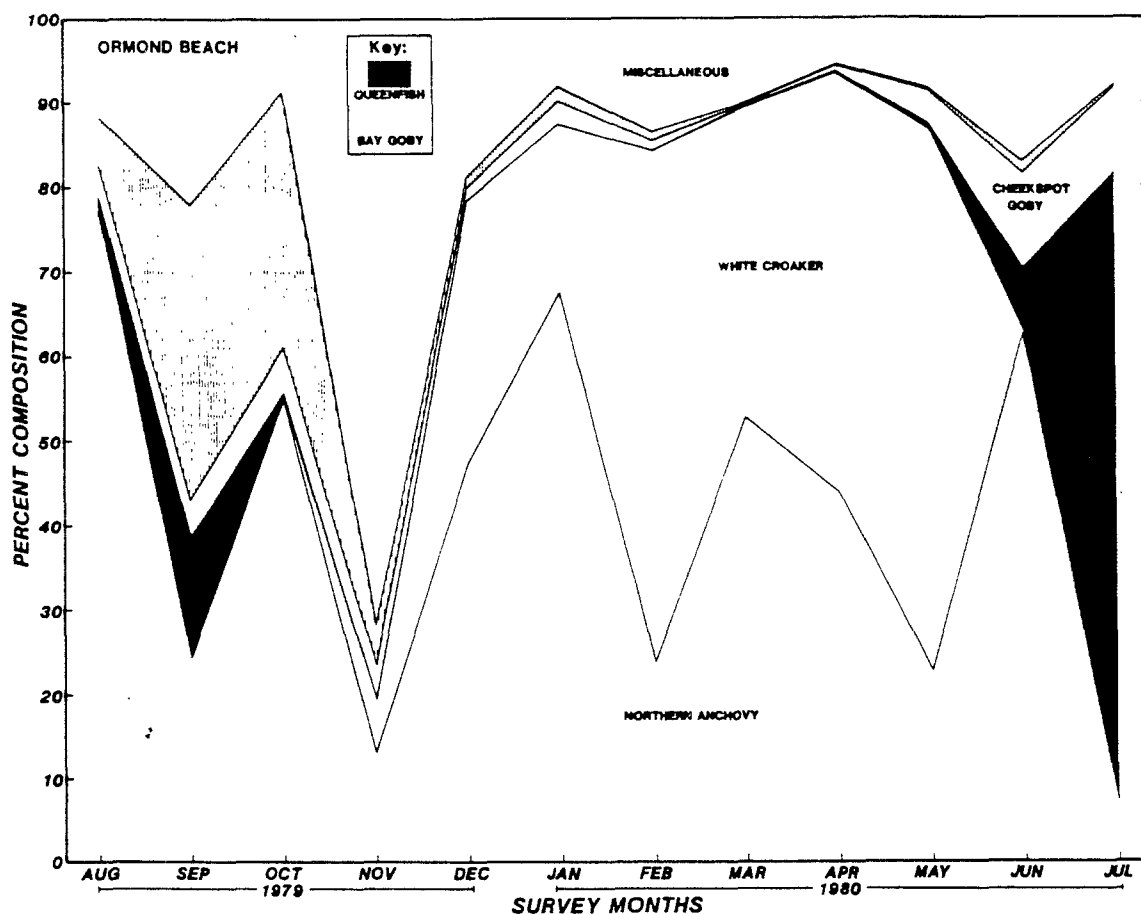


Figure 14. Monthly percent composition of abundant entrained larvae at Ormond Beach.

recently spawned) or at the end of the spawning season (late spring and early summer). The increase was least obvious in months when the results of heavy spawning activity were observed, and small larvae dominated the catch throughout the day (Figure 16).

The median size of anchovy larvae entrained at the four intakes over the 12 months of 316(b) sampling was most variable at San Onofre Unit 1 and Ormond Beach, and least variable at Redondo Beach Units 5 and 6. Median values at all four stations were lowest in December 1979 and January 1980, at the onset of the principal yearly spawning season. Highest median values were observed during September and October 1979 and June and July 1980, during the summer period of low spawning activity. Comparison of magnitudes of the median size of northern anchovy entrained monthly at each intake over the entire year and over the December to May spawning period by Kruskal-Wallis one-way analysis of variance (ANOVA; Seigel 1956) indicated that none of the intakes entrained a significantly larger size fraction than any other intake. All four intakes drew the majority of their entrained northern anchovy from size groups less than 12 mm in length (Table 4). Collections at Redondo Beach Units 5 and 6 were sporadic, and no anchovy greater than 21 mm were collected. More than 84% of the larvae collected were less than 9 mm in length. Larvae in size groups as large as 15 mm comprised a substantial proportion of collections at Ormond Beach and Redondo Beach Units 7

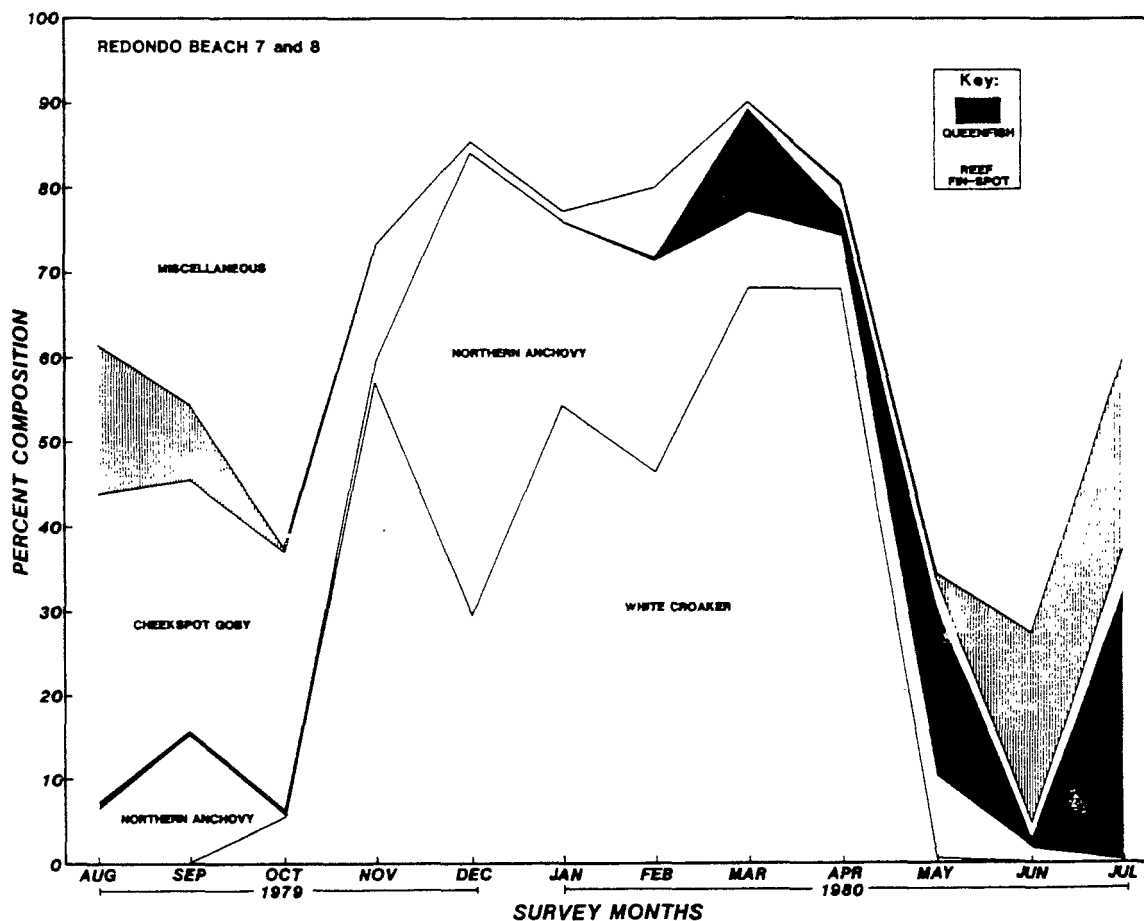


Figure 15. Monthly percent composition of abundant entrained larvae at Redondo Beach Units 7 and 8.

and 8. At San Onofre Unit 1, larvae of the 15 to 18 mm size class comprised a significant fraction of the total larvae taken. A comparison of percent entrainment by size class (Kruskal-Wallis one-way ANOVA) indicated no differences between intakes.

White Croaker

Larvae of white croaker appeared in entrainment samples more seasonally than did northern anchovy. White croaker was collected at San Onofre during 11 of 12 months, but on only 9 occasions at Ormond Beach and 8 at each Redondo Beach intake. The appearance of white croaker was generally consistent with observations of Goldberg (1976), and length-frequency distributions at all four intakes reflected these spawning trends (Figure 17). White croaker larvae are strongly associated with the epibenthic level of the water column (SCE 1980), and larvae greater than 9 mm in length were rarely collected. Median lengths of entrained larvae were less dependent on time of day than was observed for northern anchovy, and the importance of the spawning condition of adult population was less evident due to the lack of capture of larger size classes of white croaker. Increases in median length of larvae entrained after sunset were rare at all four intakes, and monthly median lengths were never greater than 6 mm until the end of the spawning season.

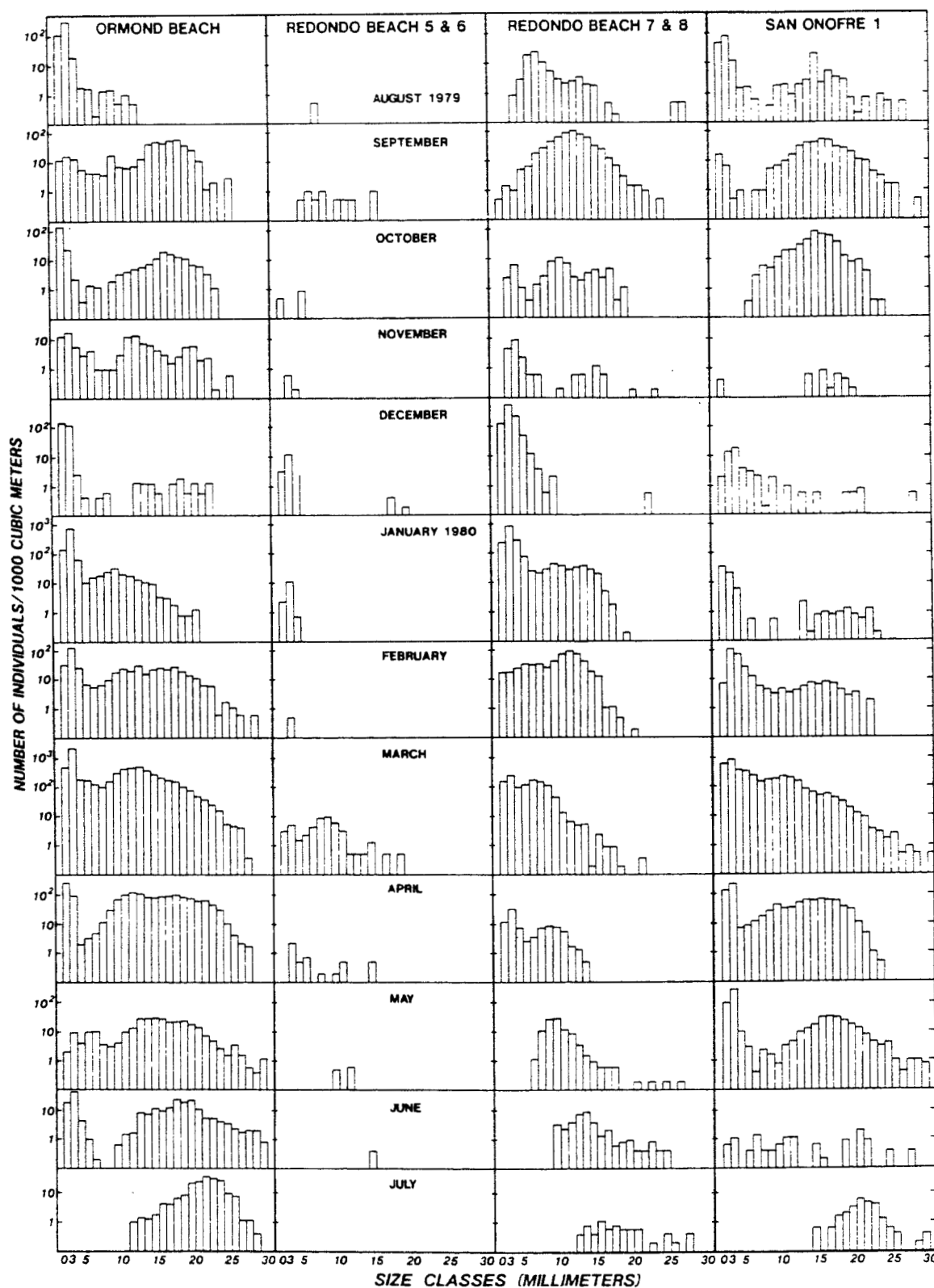


Figure 16. Monthly size-frequency distributions of northern anchovy larvae entrained at four study sites; initial size group 0-2.99 mm, and in 1 mm groups thereafter.

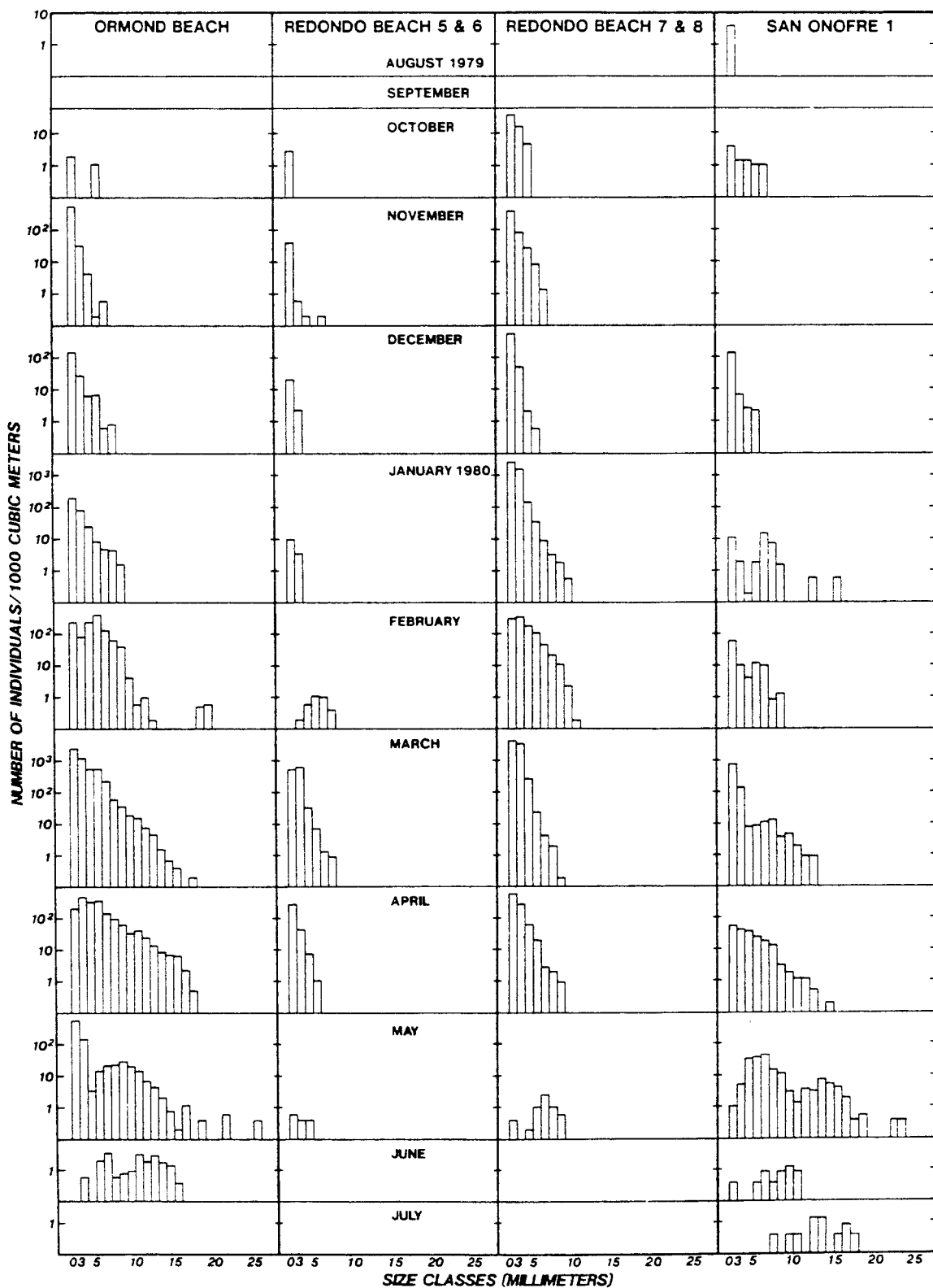


Figure 17. Monthly size-frequency distributions of white croaker larvae entrained at four study sites; initial size group 0.2-0.99 mm, and in 1 mm groups thereafter.

Variation in monthly median lengths of entrained white croaker was almost identical at all four intakes. No differences were detected between intakes when comparing the magnitude of monthly median lengths (Kruskal-Wallis one-way ANOVA). The majority of white croaker larvae entrained at all four intakes were from the 0 to 6 mm size groups (Table 5). No larvae greater than 9 mm were collected at Redondo Beach Units 5 and 6, and larvae in the 9 to 12 mm class were taken at Redondo Beach Units 7 and 8 during only one month. Larvae in size classes as large as 21 to 24 mm and 24 to 27 mm were collected on rare occasions at San Onofre Unit 1 and Ormond Beach, respectively. No differences between intakes were detected in a comparison of mean annual percent entrainment by size class (Kruskal-Wallis one-way ANOVA).

Queenfish

Larvae of queenfish were taken between March and October, corresponding to seasonal spawning habits of adult queenfish discussed by Goldberg (1976). Like white croaker, larvae of queenfish are strongly associated with the epibenthos, and individuals greater than 9 mm length were generally taken only during peak spawning months (Figure 18). Median length of entrained queenfish was not dependent on time of day, and varied only slightly over the entire sampling program. Monthly changes in median length of queenfish at all four intakes were the least variable of all three target species examined. No differences in the magnitude of the median size of entrained larvae was detected by Kruskal-Wallis one-way ANOVA.

At all four intakes the major fraction of queenfish collected was less than 6 mm in length (Table 5). No larvae greater than 21 mm were collected at either San Onofre Unit 1 or Ormond Beach, and only once at Redondo Beach Units 7 and 8. No significant differences were detected when percent mean annual entrainment by size class at each intake was compared by one-way ANOVA.

Two 316(b) key species, kelp bass and California halibut, are considered very important sport or commercial species. Larvae of kelp bass comprised only minor portions of total entrainment at any of the four sampled stations, ranging from <0.1% of the catch at Ormond Beach to 0.2% at San Onofre Unit 1. Entrainment abundance increased from the northernmost to southernmost sampled stations, and observations were restricted to late summer and early fall months at all study sites. Periods of highest abundance were observed in August or September at all stations (Figure 19).

Larvae of California halibut were more abundant, comprising up to 1.9% of total entrainment at Redondo Beach Units 7 and 8, where 82% of the total halibut were taken (Table 11). Occurrence of halibut was highest at the northernmost sampled station (observations during all months) and lowest at the southernmost (none taken in November, May, June, or July at San Onofre Unit 1). Highest abundances were observed during September at Ormond Beach and San Onofre, and during March at both Redondo Beach study locations (Figure 20).

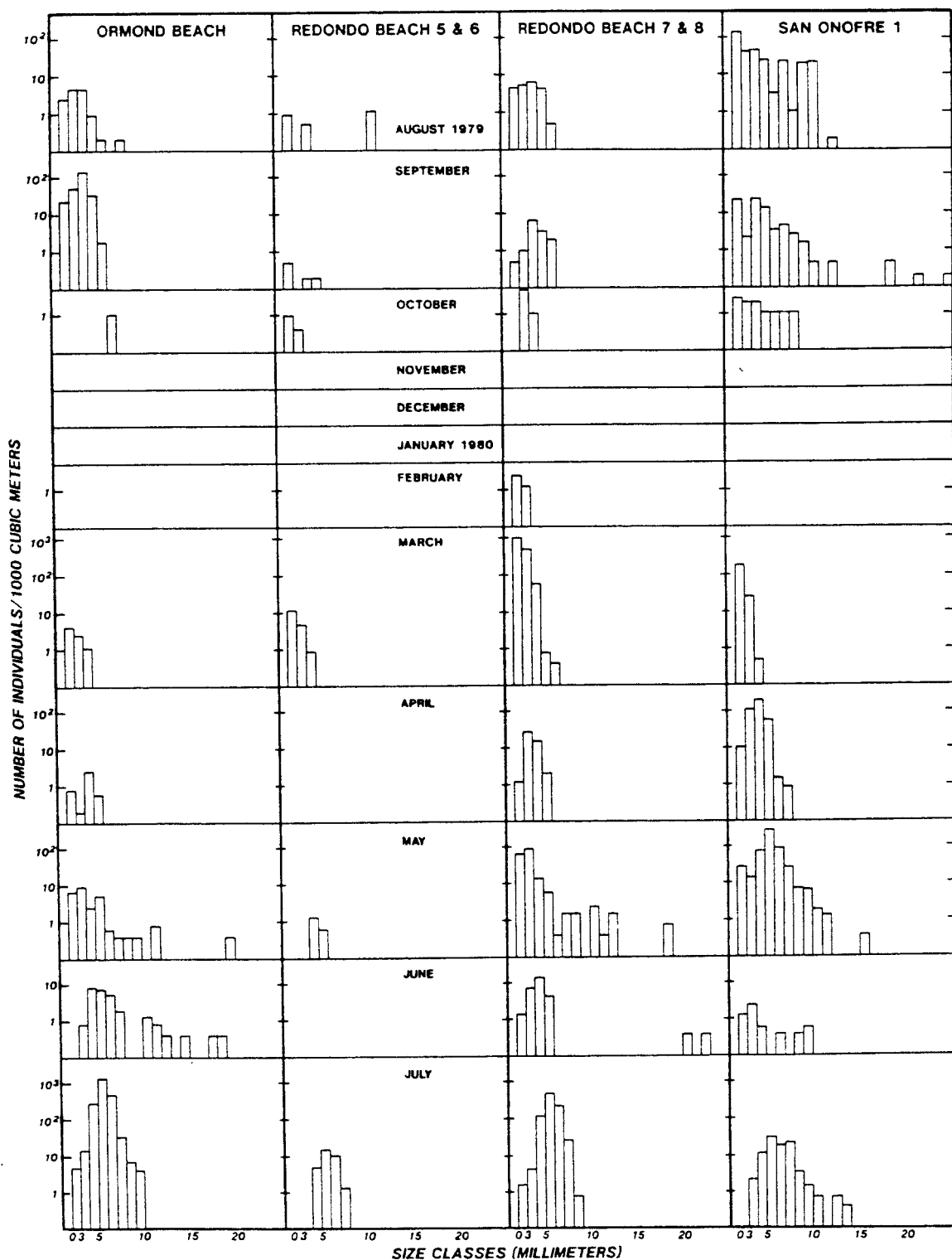


Figure 18. Monthly size-frequency distributions of queenfish larvae entrained at four study sites; initial size group 0-2.99 mm, and in 1 mm groups thereafter.

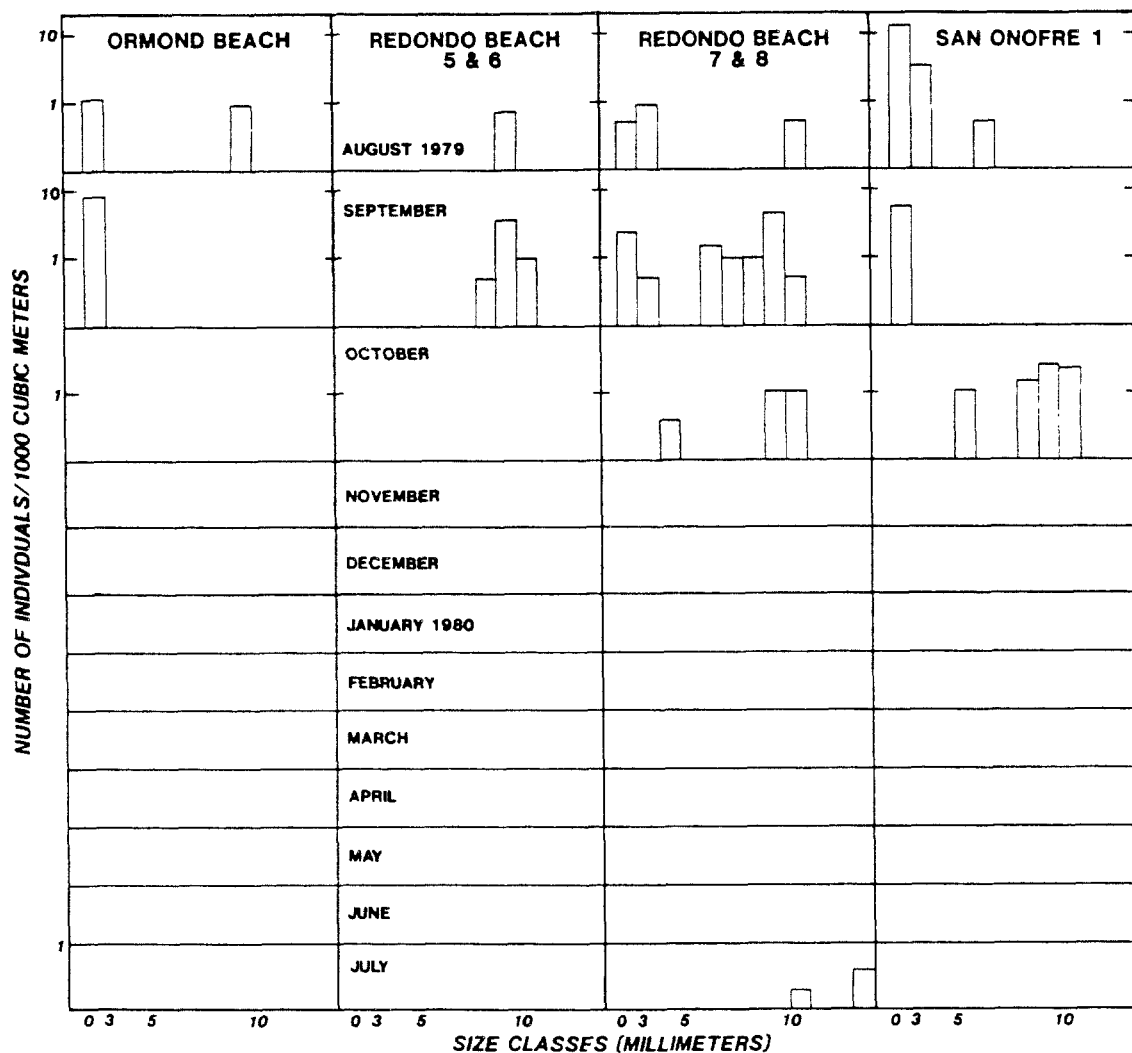


Figure 19. Monthly size-frequency distributions of kelp bass larvae entrained at four study sites; initial size group 0-2.99 mm, and in 1 mm groups thereafter.

Table 11. Summary 316(b) program yearly estimated entrainment of selected species
(mean number entrained x 10⁶).

Species	Common Name	Ormond Beach		Redondo Beach 5 & 6		Redondo Beach 7 & 8		San Onofre		Combined Total	% of Total
		Total	Rank	Total	Rank	Total	Rank	Total	Rank		
TOTAL LARVAE		2151		396		2972		691		6209	
<u>Genyonemus lineatus*</u>	white croaker	727	2	33	4	1197	1	70	3	2027	32.7
<u>Engraulis mordax*</u>	northern anchovy	900	1	2	11	428	2	312	1	1643	26.5
<u>Seriophus politus*</u>	queenfish	176	3	1	16	185	4	72	2	435	7.0
<u>Myxus gilberti</u>	cheekspot goby	42	7	128	1	199	3	37	5	406	6.5
<u>Pisces yolk sac larvae</u>	yolk sac larvae	45	6	3	9	135	5	45	4	230	3.7
<u>Paraclinus integripinnis</u>	reef finspot	<1	59	96	2	128	6	1	22	226	3.6
<u>Pisces larvae, unid.</u>	unidentified larvae	117	4	9	6	83	10	10	10	221	3.6
<u>Gibbonsia sp. A</u>	kelpfish	1	23	71	3	119	7	11	9	202	3.3
<u>Hypsoblennius spp.</u>	blenny	3	14	25	5	113	8	27	7	170	2.7
<u>Lepidogobius lepidus</u>	bay goby	66	5	1	14	5	21	29	6	103	1.7
<u>Chromis punctipinnis</u>	blacksmith	<1	31	<1	34	91	9	-	-	92	1.5
<u>Paralichthys californicus/</u> <u>Xystreus tirolepis</u>	California halibut/ fantail sole	5	10	<1	23	57	11	6	15	69	1.1
<u>Gobiesox rhesodon</u>	California clingfish	<1	54	3	8	45	12	7	13	55	0.9
<u>Gobiidae type D</u>	goby	14	8	<1	18	39	13	<1	28	55	0.9
<u>Sardinops sagax caeruleus</u>	Pacific sardine	2	18	<1	32	14	15	<1	30	17	0.3
<u>Menticirrhus undulatus</u>	California corbina	<1	63	-	-	<1	48	15	8	16	0.3
<u>Atherinopsis californiensis</u>	jacksmelt	<1	24	<1	39	1	35	10	11	12	0.2
<u>Heterostichus rostratus</u>	giant kelp fish	<1	30	2	10	3	26	2	20	8	0.1
<u>Roncador stearnsii*</u>	spotfin croaker	-	-	-	-	-	-	8	12	8	0.1
<u>Paralabrax clathratus*</u>	kelp bass	2	19	<1	27	2	36	2	21	6	0.1
<u>Peprilus simillimus*</u>	Pacific butterfish	1	22	<1	58	<1	40	<1	25	3	<0.1
<u>Paralabrax nebulifer</u>	barred sand bass	2	20	-	-	<1	48	<1	66	2	<0.1
<u>Anisotremus davidsoni*</u>	sargo	<1	47	<1	62	<1	44	<1	27	1	<0.1
<u>Cheilotrema saturnum*</u>	black croaker	<1	37	<1	55	<1	55	<1	23	1	<0.1
<u>Umbrina roncadore*</u>	yellowfin croaker	<1	42	-	-	-	-	-	-	<1	<0.1
<u>Sebastes paucispinis*</u>	bocaccio	-	-	-	-	-	-	-	-	-	-
All Others		35		14		97		22		164	2.4

*316(b) target species

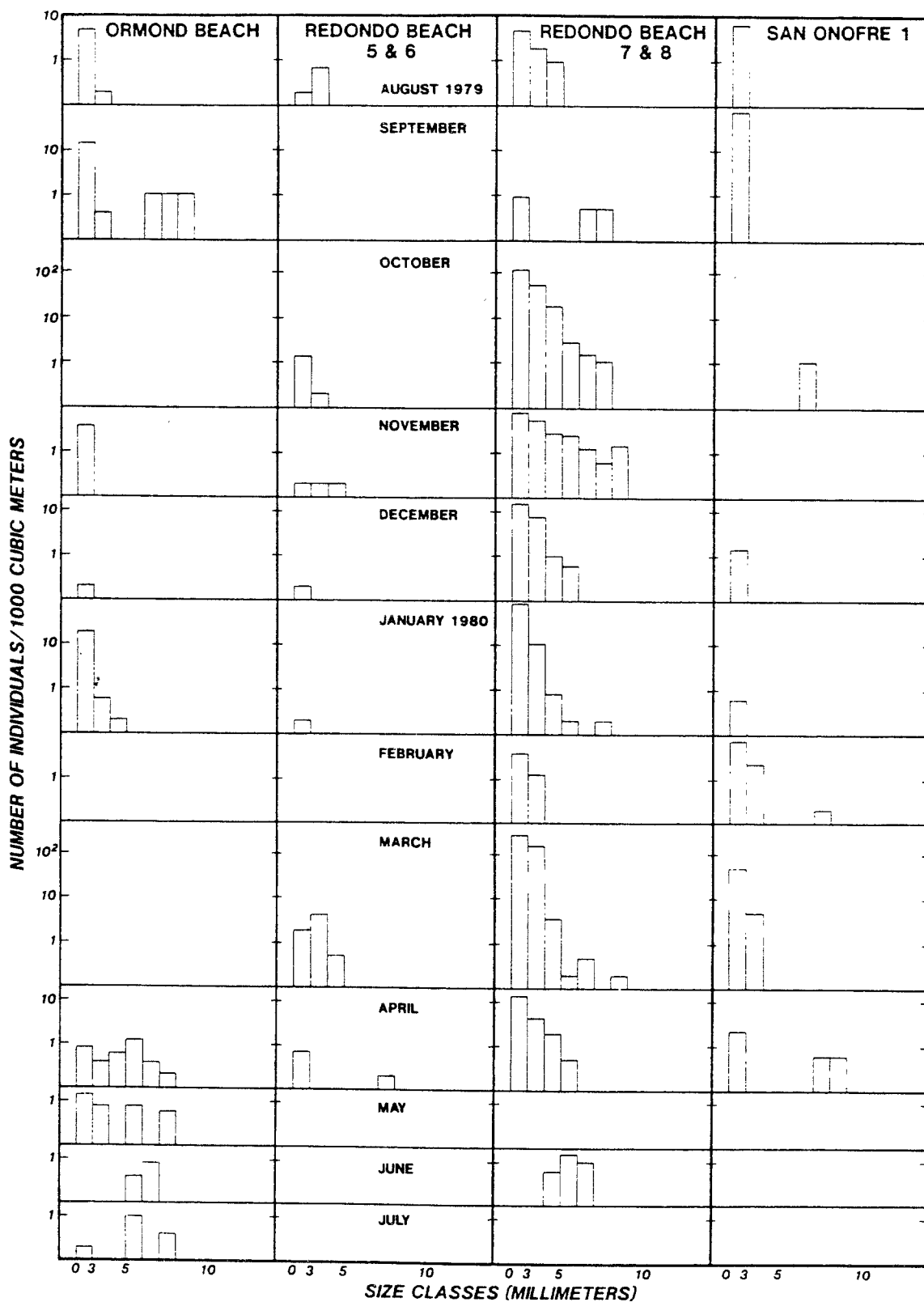


Figure 20. Monthly size-frequency distributions of California halibut larvae entrained at four study sites; initial size group 0-2.99 mm, and in 1 mm groups thereafter.

CHAPTER 3

ENTRAINMENT MASS BALANCE

INTRODUCTION

Changes in ichthyoplankton concentrations during transit of generating station cooling water systems were determined to provide quantitative information in support of a demonstration to satisfy requirements of Section 316(b) of the 1972 Amendments to the FWPCA. Observations of ichthyoplankton abundance in samples pumped from circulating water system intake and discharge risers were made at San Onofre Unit 1 during two 24-hr periods in March 1980, and during three 24-hr periods in September 1980 at Ormond Beach. The multiple observations were designed to allow seasonal comparisons of: 1) system transit success at representative stations; 2) changes in species composition and size classes entrained; and 3) changes in maximum temperature exposure (ΔT) to entrained organisms, as well as to compare success rates relative to the accumulated biomass of the biofouling community.

Sampling protocol was identical to that previously described for the entrainment inventory portion of this study, except that samples were collected from within the discharge riser as well as the intake riser, allowing a suitable lag time at the discharge riser to sample the same water parcel as was encountered at the intake. Entrainment of ambient water from outside the discharge was observed by releasing dye around the lip of the discharge riser. Contamination of discharge samples was avoided by inserting the discharge sampling device well below the level of observed contamination. Percent transit success for each replicate was determined by comparing concentrations of larvae taken in discharge samples to concentrations observed in intake samples.

BACKGROUND

Previous studies of zooplankton and ichthyoplankton entrainment by generating station cooling water systems have observed differential concentrations of animals (lower in discharge samples) between intake and discharge collections (MBC 1975, Marine Review Committee [MRC] 1978). These studies indicated that 50 to 100% of the entrained organisms were lost during station transit, and that the magnitude of loss appeared to be associated with the biomass of fouling organisms present in the cooling system conduits (MBC 1975, MRC 1979).

Several factors may account for the reported loss of entrained organisms during station transit, including: 1) destruction from abrasion, shear stress, pressure, and heat associated with cooling system passage; 2) predation by conduit biofouling organisms; and 3) predation by planktivores entrained and existing in the station screenwell.

Studies by the Lockheed Center for Marine Research (1977) indicated the biomass of the biofouling community on the walls of the cooling system conduits at San Onofre Unit 1 increased substantially between heat treatments. Predation by biofouling organisms may thereby be a significant factor in the removal of entrained larvae during certain phases of the biofouling control cycle.

While smaller water column planktivores (northern anchovy, queenfish) are removed from generating station screenwells through impingement collections on a daily basis, larger strong-swimming types (jacksmelt, croakers, kelp bass,

topsmelt, blacksmith) may be able to exist within the screenwell between heat treatments, and could account for a portion of larval loss during station transit. However, a relatively small number of adults commonly taken during heat treatments are planktivorous.

It was believed that the major factor in loss of organisms through the cooling system was predation by the biofouling community; therefore, the study was designed around this variable. The rationale for examining station transit success during several phases of the biofouling control cycle was based on the assumptions that: 1) cropping losses immediately following a heat treatment could be attributed mainly to the effects of abrasion, shear, and heat stress, and would represent a similar component of loss during all phases; 2) cropping losses would be highest just prior to a heat treatment, with a well-established fouling community and maximum numbers of large planktivores in the cooling system; and 3) a mid-cycle sampling series would estimate cropping losses at an intermediate level.

Two criteria were established for selection of a representative site to determine ichthyoplankton loss through plant cropping loss: 1) the generating station with the longest intake and discharge conduit; and 2) the generating facility where maximum information on conduit grazing was available. The former criterion was established based on the assumption of biofouling community cropping as the major influence on cropping of larvae during transit. The facility with the longest intake and discharge conduit (San Onofre Unit 1) would expose transiting larvae to the largest potential surface area of fouling community biomass. The latter criterion was based on other related studies completed and proposed at San Onofre, which would add to an information base to predict system-wide intake loss. The studies were planned at San Onofre, but because Unit 1 went off-line in April 1980, the second set of mass balance studies had to be moved to another site chosen to be as similar as possible to San Onofre (Ormond Beach Generating Station). The overall length of the intake and discharge conduit at Ormond Beach is 11% shorter than at San Onofre Unit 1, but the inner surface area of the Ormond Beach conduit is 3.2% greater.

REPRESENTATIVE DISCHARGE SAMPLING POSITION

A sampling position within the discharge riser was desired that was free of contamination by ambient water entrained over the edge of the riser lip by the discharge plume. Dye releases along the edges of the riser were conducted to determine the extent of penetration of secondarily entrained water into the discharge bowl. The discharge sampling device was then placed in a position well below the observed penetration point. Dye releases were conducted at both San Onofre Unit 1 and Ormond Beach prior to the initial mass balance study at each site (Table 12).

SUMMARY OF RESULTS AND DISCUSSION

SUMMARIZED RESULTS

A summary table of intake concentration and transit success of all 316(b) target species and the seven most abundant non-target taxa (from Chapter 2) is presented in Table 13. Transit success of the entire larval assemblage entrained in March samples at San Onofre was strongly influenced by the dominance of target species in sample collections. During both Phases II and III transit success of abundant non-target taxa was generally higher than overall success, which was reduced by the high concentrations (and low transit success) of northern anchovy larvae. Entrainment concentrations were an order of magnitude lower, and transit success for many species higher, in summer collections at Ormond Beach.

Table 12. Mass balance studies conducted during 1980 316(b) ichthyoplankton sampling.

Station Cycle/Event	San Onofre Unit 1	Ormond Beach	Phase
Heat Treatment	13 January	17 August	I
Mid-point Survey	plant not operating	3-4 September	
Prior to Heat			
Treatment Survey	12-13 March	22-23 September	II
Heat Treatment	23 March	26 September	
After Heat			
Treatment Survey	26-27 March	29-30 September	III

>90% of the total observed for all three species (Chapter 2), indicating that variability in transit success in larger size classes may be due to variability in intake concentrations. Transit success in these larger classes is generally high, however.

Based on the transit success:entrainment abundance ratio (Figure 21), percent success of station transit for the two individual stations was estimated. Median daily larval entrainment during the 316(b) Ichthyoplankton Entrainment Program at Ormond Beach and San Onofre Unit 1 was 4.173×10^6 and 1.742×10^6 individuals per day, respectively. Percent transit success for the two stations based on the regression was 45.0 and 52.6%, respectively.

COMPARISON OF SEASONAL ENTRAINMENT MASS BALANCE

Although the two mass balance studies were conducted six months apart, at two separate sampling sites, and under different environmental conditions and settings, the major components of the communities entrained were relatively similar. Northern anchovy, white croaker, and/or queenfish larvae were among the major species entrained in both studies. Differences in the density of these species between the two studies were substantial, however, and are related to the reproductive cycle of the individual species. The prominence of larval cheekspot goby in September samples at Ormond Beach is attributed to differences in the structure of the ichthyoplankton community present at San Onofre Unit 1 and

Table 13. Summary overall percent transit success — 316(b) target species and abundant non-target species.

Species	San Onofre				Ormond Beach					
	Prior to Heat		After Heat		Mid-point		Prior to Heat		After Heat	
	Conc.*	%	Conc.*	%	Conc.*	%	Conc.*	%	Conc.*	%
northern anchovy	818.2	13.9	952.5	10.8	58.6	70.2	53.7	76.1	2.0	>100.0
white croaker	194.6	22.8	208.8	46.4	*	-	0.1	0.0	**	-
queenfish	42.7	12.3	38.4	72.4	22.8	56.0	9.3	33.7	2.9	59.9
Pacific butterflyfish	0.6	0.0	2.1	0.0	**	-	**	-	**	-
kelp bass	**	-	**	-	0.6	0.0	0.1	0.0	0.5	0.0
barred sand bass	**	-	**	-	**	-	**	-	**	-
sargo	**	-	**	-	**	-	**	-	**	-
spotfin croaker	**	-	**	-	**	-	0.1	0.0	**	-
bocaccio	**	-	**	-	**	-	**	-	**	-
black croaker	0.2	42.0	0.5	0.0	**	-	**	-	**	-
yellowfin croaker	**	-	**	-	**	-	**	-	**	-
cheekspot goby	11.1	27.9	1.4	>100.0	11.0	8.4	66.7	26.4	15.7	50.2
yolk sac larvae	124.9	9.5	74.6	1.9	0.3	42.0	0.4	47.6	0.4	30.4
reef finspot	**	-	**	-	**	>100.0	**	>100.0	**	-
unidentified larvae	48.7	30.6	17.1	72.0	5.0	97.5	4.7	40.9	1.5	36.6
kelpfish	2.4	30.4	0.4	93.4	0.3	0.0	0.4	36.2	**	-
blenny	2.3	23.2	2.1	37.0	3.0	41.9	2.7	10.2	1.5	49.3
bay goby	7.2	78.2	3.9	90.5	0.1	0.0	1.5	18.4	**	-
Phase Total	1280.8	16.3	1314.8	19.1	121.9	59.5	163.1	43.8	37.2	60.2
Season Total		1297.8	18.5				107.4	51.6		
Study Total				583.6	22.2					

*daily entrainment (number $\times 10^4$)

**not collected in intake samples

Table 14. Summary percent transit success by size class of three major target species.

Species	Size Class	San Onofre		Ormond Beach			Total
		Prior to Heat	After Heat	Mid-Point	Prior to Heat	After Heat	
northern anchovy	0-3	6.5	3.4	>100.0	>100.0	0.0	4.5
	3-6	9.5	9.5	63.3	*	0.0	8.1
	6-9	20.0	36.0	30.3	*	11.8	20.9
	9-12	22.5	33.5	78.9	>100.0	>100.0	28.9
	12-15	24.5	35.0	95.6	82.0	>100.0	38.2
	15-18	28.5	35.3	67.7	63.0	>100.0	45.6
	18-21	24.2	45.5	95.6	>100.0	>100.0	38.7
	21-24	56.5	54.2	>100.0	*	>100.0	62.8
	24-27	31.0	28.6	0.0	*	*	36.5
	27-30	0.0	>100.0	*	*	*	27.8
	Phase %	13.9	10.8	70.2	76.1	>100.0	
	Seasonal %		12.2		75.2		
	Total %			15.1			
white croaker	0-3	24.9	14.4	*	0.0	*	21.5
	3-6	45.5	51.9	*	*	*	48.6
	6-9	68.1	57.7	*	*	*	58.2
	9-12	38.9	37.0	*	*	*	46.2
	12-15	>100.0	>100.0	*	*	*	>100.0
	Phase %	22.8	46.4	*	0.0	*	
queenfish	0-3	12.6	16.4	>100.0	0.0	0.0	15.1
	3-6	0.0	95.5	33.8	39.2	60.7	67.8
	6-9	*	>100.0	22.2	0.0	100.0	26.5
	9-12	*	0.0	*	*	*	0.0
	12-15	*	*	*	*	*	>100.0
	Phase %	12.3	72.4	56.0	33.3	59.9	
	Seasonal %		40.9		50.2		
	Total %			43.2			

* Not collected in intake samples.

Ormond Beach. As was detailed in the entrainment inventory chapter of this report, larvae of cheekspot goby are a major component of the Ormond Beach ichthyoplankton community during much of the year.

The relative importance of Mexican lampfish larvae in the ichthyoplankton community at Ormond Beach was probably the result of: 1) the reduced density of other components of the larval community near Ormond Beach; and 2) the close proximity of Ormond Beach to deeper waters (a submarine canyon). Mexican lampfish spawn in offshore waters (Ahlstrom 1965); thus, their larvae do not normally form a major fraction of the inshore community (see entrainment inventory section). Densities of Mexican lampfish larvae in September 1980 samples from Ormond Beach were considerably higher than previously recorded in the area (September 1979), while the density of other species that previously comprised a major

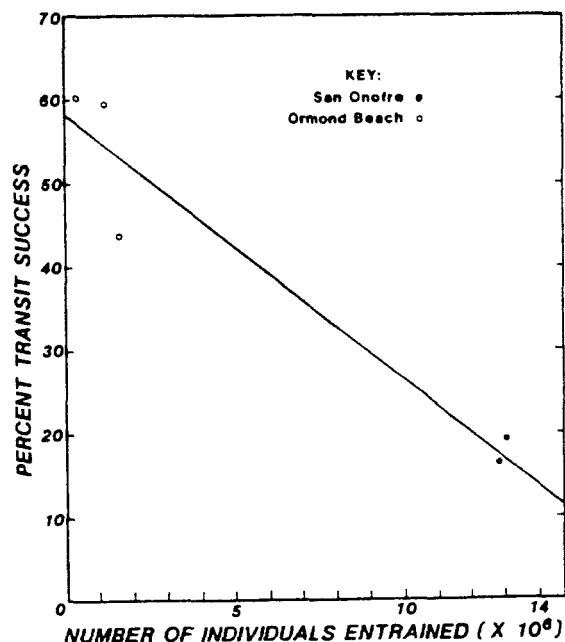


Figure 21. Least-squares regression of percent transit success versus entrainment sample abundance at Ormond Beach and San Onofre Unit 1 during the mass balance study.

fraction of the Ormond Beach ichthyoplankton community (northern anchovy, white croaker, queenfish, and cheekspot goby) were approaching or had reached their seasonal low. The close proximity of Ormond Beach to a submarine canyon, and a possible spawning population of Mexican lampfish, was likely a major factor in the densities of larvae observed.

Larval densities increased substantially between the daylight and night sampling periods in both winter and summer mass balance studies, as well as during a majority of the entrainment inventory investigations discussed previously. This phenomenon has also been reported from various inshore sampling programs in southern California (SCE 1980, Barnett et al. 1978, MBC unpublished data). The decrease in larval densities observed in these latter studies during daylight sampling periods may be the result of net avoidance by (at least) the older (larger) portion of the larval community (Smith and Richardson 1977, Methot and Kramer 1979) which is capable of detecting approaching nets and are able to sustain swimming speeds sufficient for avoidance. Older larvae may also be capable of avoiding intake entrainment. The cue for avoidance may be either visual or a reaction to slight changes in current speeds. In periods of darkness larvae lack the cues necessary to avoid the intake, or become disoriented and more susceptible to entrainment.

There is only circumstantial evidence for diurnal vertical migration by nearshore larvae (SCE 1980); however, a migration pattern of this type would help explain: 1) the increase of entrainment densities at night; and 2) the entrainment of larger larvae, specifically northern anchovy, queenfish, and white croaker, at night. Older larvae of a majority of nearshore fish inhabit the epibenthic zone of the water column, at least at night (SCE 1980). Older larvae of these species may either migrate from the upper water column to the epibenthic zone during the night, or migrate from the epibenthos into the lower water column. During the migratory process larvae come in contact with intake-induced currents and are susceptible to entrainment.

Differences in transit success between pre-heat treatment (Phase II) and post-heat treatment (Phase III) sampling periods at San Onofre Unit 1 was strongly influenced by the dominance of target species larvae in entrainment samples. Overall larval transit success during both phases was highly dependent on percent abundance of target species, and while differences were noted between the two phases for all three species, they appear to be less related to the conduit biomass accumulated than to the size-frequency distribution of the entrained larvae. During Phase III (post-heat treatment), median lengths of entrained white croaker and queenfish were larger than those observed during Phase II (Table 15), while the median length of entrained northern anchovy declined. Similar trends were noted for percent transit success in all three species, with higher success rates observed in larger size classes when a sufficient number of individuals was present to allow meaningful analysis.

Table 15. San Onofre Unit 1 mass balance study - Winter Phases II and III. Intake concentrations - Percent composition by size class.

Size Class (mm)	<u>Engraulis mordax</u>		<u>Geryonemus lineatus</u>		<u>Seriophus politus</u>	
	Phase II	Phase III	Phase II	Phase III	Phase II	Phase III
0-3	30.4	68.9	93.4	21.2	98.3	33.1
3-6	29.4	10.6	3.4	77.3	1.7	66.6
6-9	13.3	4.8	2.5	1.3	-	-
9-12	15.8	9.3	0.7	0.2	-	0.2
12-15	5.9	4.7	-	-	-	-
15-18	3.6	1.5	-	-	-	-
18-21	1.2	0.2	-	-	-	-
21-24	0.3	0.05	-	-	-	-
24-27	0.1	0.01	-	-	-	-
27-30	0.05	-	-	-	-	-

Percent transit success for total entrained larvae during summer mass balance studies at Ormond Beach was lowest just prior to heat treatment and highest just after heat treatment, corresponding to expected results from reference to biofouling studies at San Onofre Unit 1 by Lockheed Center for Marine Research (1977). Heat treatments were anticipated to reduce conduit biofouling and increase transit success by eliminating predation as a transit mortality factor in the period following a heat treatment. The pattern was not always repeated, however, in the four species contributing most to mass balance entrainment concentrations. Only larval queenfish followed the pattern observed for total larvae. Increased transit success during Phase II (prior to heat treatment) for northern anchovy may be attributed to the increased median size distribution of the individuals present (Table 16), while the success of >100% during Phase III is due to high variability resulting from very low larval concentrations in the source waters.

Comparisons between the San Onofre and Ormond Beach studies indicate that transit success for all larvae combined and larvae of individual target species was substantially lower in March. Several factors could be responsible for these differential transit success rates: 1) success is affected by ambient water temperature offshore (i.e. higher temperature results in less success); 2) size frequency distributions of target larvae were substantially different (i.e. larger organisms results in more success); 3) overall success was affected by species composition (some species may be more resistant to damage); 4) transit success is affected by density of entrained larvae (i.e. higher larval concentrations results in less transit success); or 5) transit success is affected by differences in cooling system configuration and operation.

Water temperatures offshore Ormond Beach were essentially similar during all three phases of summer mass balance studies. Surface temperatures were consistently near 17°C, and little water column stratification was noted. Surface temperatures and water column profiles during winter studies at San Onofre Unit 1 were substantially identical to those observed at Ormond Beach.

Size frequency distributions in Ormond Beach studies were only slightly different from those observed in San Onofre studies (Tables 15 and 16). Median size frequencies of northern anchovy were slightly larger in summer studies, as were distributions of queenfish. Essentially no white croaker were observed in summer studies. Size of individual larvae during transit is probably a significant factor in determining transit survival. However, increased transit success in summer studies may have been influenced by the variability of occurrence of target species.

Species composition may have a significant effect on overall transit success of the larval community entrained by the intake. During winter studies

Table 16. Ormond Beach mass balance study — Summer Phases I-III. Intake concentrations — Percent composition by size class.

Size Class (mm)	<u>Engraulis mordax</u>			<u>Genyonemus lineatus</u>			<u>Seriphus politus</u>		
	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
0-3	1.5	-	7.4	-	100.0	-	32.7	2.8	6.9
3-6	59.6	-	11.8	-	-	-	66.2	84.7	83.2
6-9	7.4	-	25.0	-	-	-	1.1	12.5	9.9
9-12	8.7	2.9	8.8	-	-	-	-	-	-
12-15	14.0	56.9	10.3	-	-	-	-	-	-
15-18	7.6	38.7	27.9	-	-	-	-	-	-
18-21	1.1	1.6	8.8	-	-	-	-	-	-
21-24	-	-	-	-	-	-	-	-	-
24-27	0.2	-	-	-	-	-	-	-	-
27-30	-	-	-	-	-	-	-	-	-

yolk sac and halibut larvae were abundant fractions of the entrained community, and both taxa experienced extremely low transit success. These taxa were less abundant during summer studies and occasionally did not occur in samples. However, transit success of these taxa was higher during summer studies.

An important factor determining transit success for all larvae combined and certain target species may be the density of entrained larvae. Overall mean density ($\#/1000\text{m}^3$) of total larvae and northern anchovy during the winter studies was 16.4 and 31.6 times greater, respectively, than during summer studies. High densities of larvae during plant passage may significantly affect transit success due to abrasion, suffocation, magnification of shear or compression forces, and loss of orientation.

Some differences in transit success may be due to differences in the configuration and operation of the cooling water systems at San Onofre Unit 1 and Ormond Beach. In general, ambient water temperatures at Ormond Beach are lower than those observed at San Onofre (SCE 1982). The biofouling community associated with the Ormond Beach system may be substantially different from that at San Onofre. Other factors include differences in conduit length, type of circulating water pumps used, and condenser configuration.

EFFECT OF POTENTIAL LOSS ON ESTIMATES OF ENTRAINMENT

Results of the mass balance studies indicate that under some conditions transit success of entrained larvae could significantly alter entrainment loss estimates if subsequent survival of entrained larvae is established. No attempt was made to establish actual survivorship rates, however. Estimates of transit success are reported as simple ratios of discharge:intake concentration.

The major factors determining transit success of individual larvae appear to be: 1) size of the entrained individual; and 2) the overall density of the entrained larval assemblage. During winter mass balance studies at San Onofre Unit 1, very high concentrations of larvae and the dominance of small individuals of important target species resulted in low rates of transit success. The success rate may have been further reduced by the relatively low ratio of entrained volume:conduit surface area at San Onofre Unit 1 (Schlotterbeck et al. 1979a), and the length of the cooling system conduit which resulted in a longer exposure period to the biofouling community and physical effects. Mean overall transit success rates ranged between 16.3 and 19.1% during the two sampling phases (pre-heat and post-heat, respectively).

Summer mass balance studies at Ormond Beach were marked by mean larval concentrations only 6% as high as those observed during winter studies. Mean transit success rates ranged between 43.8 and 60.2% for the three study phases. Success rates were slightly increased by the occurrence of greater than 100% survival rates observed for several species.

Concentrations of entrained larvae collected at San Onofre Unit 1 during winter mass balance studies were among the highest observed at that intake in three years of sampling (SCE 1980). Conversely, larval concentrations observed at Ormond Beach during summer mass balance studies were among the lowest collected at any of the four intakes sampled during the 316(b) ichthyoplankton entrainment program. A realistic estimate of larval transit success based on median larval entrainment levels is probably near the mean of the transit success rates (not necessarily survival) determined for the two seasonal studies. This conclusion is based on several factors: 1) the configuration of the two intakes withdrawing primarily offshore water is similar; 2) the community structure of the larval assemblages affected by each of those intakes is similar; and 3) intake volumes

and flow rates are not substantially different. While the longer conduit and slightly lower entrained volume:conduit surface area ratio at San Onofre Unit 1 may result in lower success rates at that location, the overall mean annual transit success rate for intakes withdrawing from offshore water sources in the SCE system is probably higher.

METHODS

REPRESENTATIVE DISCHARGE SAMPLING POSITION

Release of Rhodamine B dye along the lip of the discharge bowl (Figure 22) and subsequent diver observation at San Onofre Unit 1 on 12 March 1980 at 1705 hrs indicated that the inshore release did not enter the discharge, while the offshore, upcoast, downcoast, and two center dye releases did enter the discharge riser. No dye was observed passing through the sampling pumps or in the pump discharge waters.

On 26 March 1980 at 1610 hrs at San Onofre Unit 1 Rhodamine B dye was again released. Divers observed large vortices of dye entering the discharge riser from the inshore release. This dye was entrained to a depth of 2 m. Smaller laminar dye flow was observed to enter from the upcoast and downcoast releases. The offshore dye release was entrained about 1 m and then moved to the surface rapidly. In the laboratory, dye was detected in one of the 24 samples (T_{release} + 10 min), indicating contamination from ambient waters.

The final dye release was at Ormond Beach on 3 September 1980 at 1645 hrs. The discharge sampling pipe (5.8 m) was nearly twice the length as the pipe employed at San Onofre Unit 1 (3.1 m). Diver observations of dye indicated a downcoast current, which resulted in entrainment of ambient water along the inshore and downcoast sides of the discharge riser. Dye was observed to enter the riser to a depth of 2.5 m. No dye was detected in any of the 20 samples collected from the pump discharge (on board fluorometric analysis), indicating an absence of contamination by ambient waters.

Transit times for circulating water was determined by release of dye at the intake and its subsequent observation at the discharge. At San Onofre the transit times were 00:17:43 on 12 March 1980 and 00:17:28 on 26 March 1980. At Ormond Beach the transit times were 00:14:28 on 3 September and 22 September 1980 and 00:14:00 on 29 September 1980.

SAMPLING PROTOCOL

Mass balance studies were conducted at San Onofre on 12-13 March and 26-27 March 1980 and at Ormond Beach on 3-4, 22-23, and 29-30 September 1980 (Table 12).

The sampling regime was the same as used in the entrainment inventory, except samples were also collected from the discharge using a 15.2 cm diameter fiberglass pipe (DIC - discharge ichthyoplankton sampler) that was inserted 5.8 m (3.1 m at San Onofre) into the discharge riser (Figure 22). To achieve a sampling point which would reduce contamination from ambient waters to a minimum, the pipe was placed 0.6 m seaward of the centerpoint of the discharge based on the recommendations of Dr. John List of the California Institute of Technology.

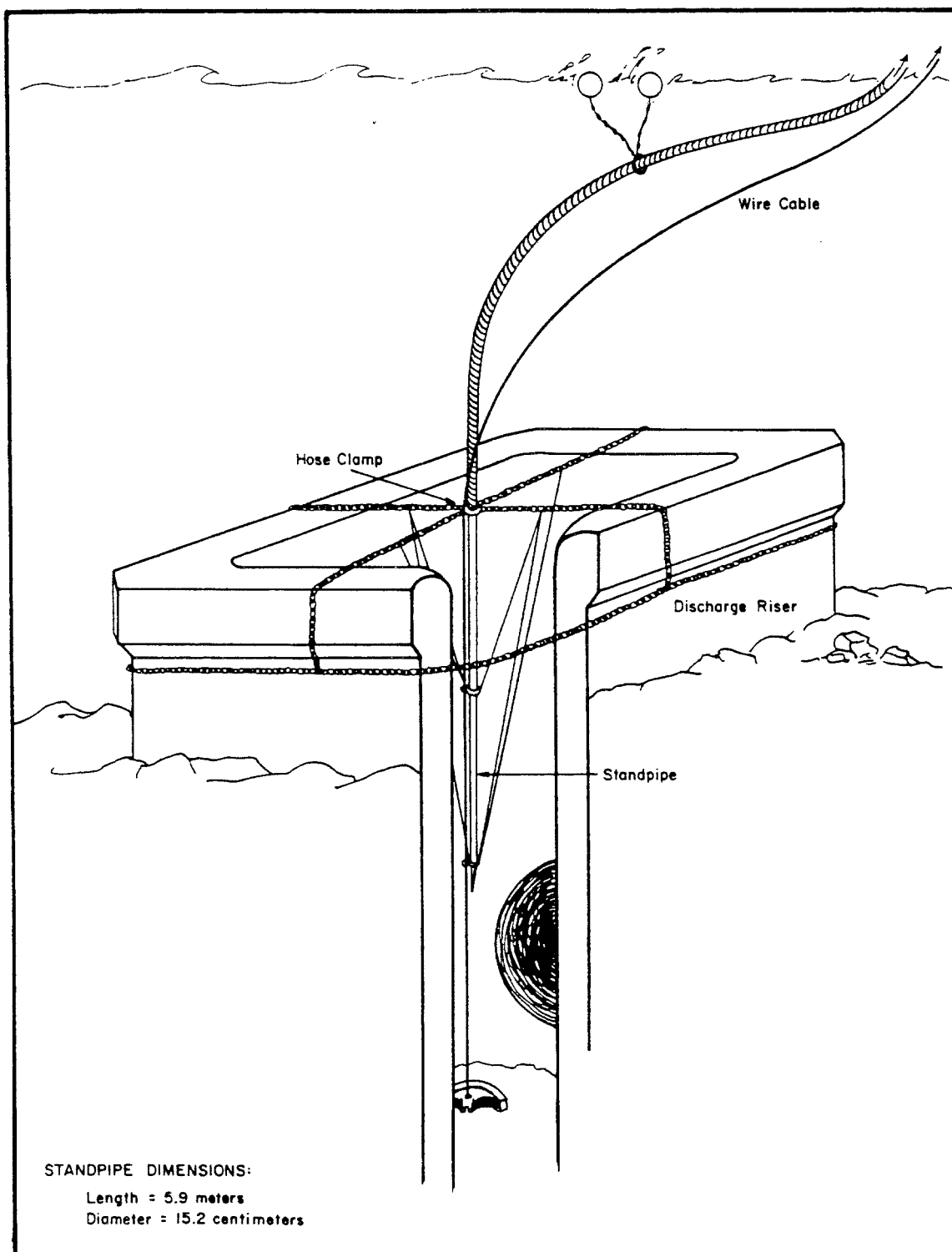


Figure 22. Deployment configuration of the Discharge Ichthyoplankton Collector (DIC), holding the collection port below the observed level of ambient water contamination.

RESULTS AND ANALYSES

SPECIES COMPOSITIONWinter

A total of 21 and 24 taxa were collected at San Onofre Unit 1 during the Phase II and Phase III mass balance studies, respectively. Three species (northern anchovy, white croaker, and queenfish) comprised the majority of larvae collected. Northern anchovy comprised 64.4% of the larvae entrained during Phase II, and 72.4% during Phase III. Larval densities were highest between evening and sunrise (2100 to 0743 hrs) during Phase II, while maximum densities were recorded between the sunset and sunrise sampling periods (1706 to 0646 hrs) in Phase III (Figure 23).

White croaker larvae were the second major species collected, comprising 14% of the ichthyoplankton community in both Phase II and Phase III. This species was most abundant during the evening and night sampling periods of both phases.

Queenfish larvae were the third major species collected. Queenfish comprised approximately 3% of the catch during both phases of the study. Maximum densities of larvae were recorded during the night sampling period (approximately 0100 to 0330 hrs) of both phases.

Unidentified yolk sac larvae were relatively abundant during both Phase II and Phase III, representing approximately 10.5 and 6.0%, respectively of the catch. The majority of these larvae were extremely young and taxonomic characteristics used for species identification are poorly developed. Shape and pigment patterns suggest that the larvae were either white croaker or queenfish.

During Phase II, larvae of jacksmelt, cheekspot goby, bay goby, and California halibut were common in collections made between sunset and sunrise. No larvae in Phase III, other than those previously discussed, were of importance in terms of density.

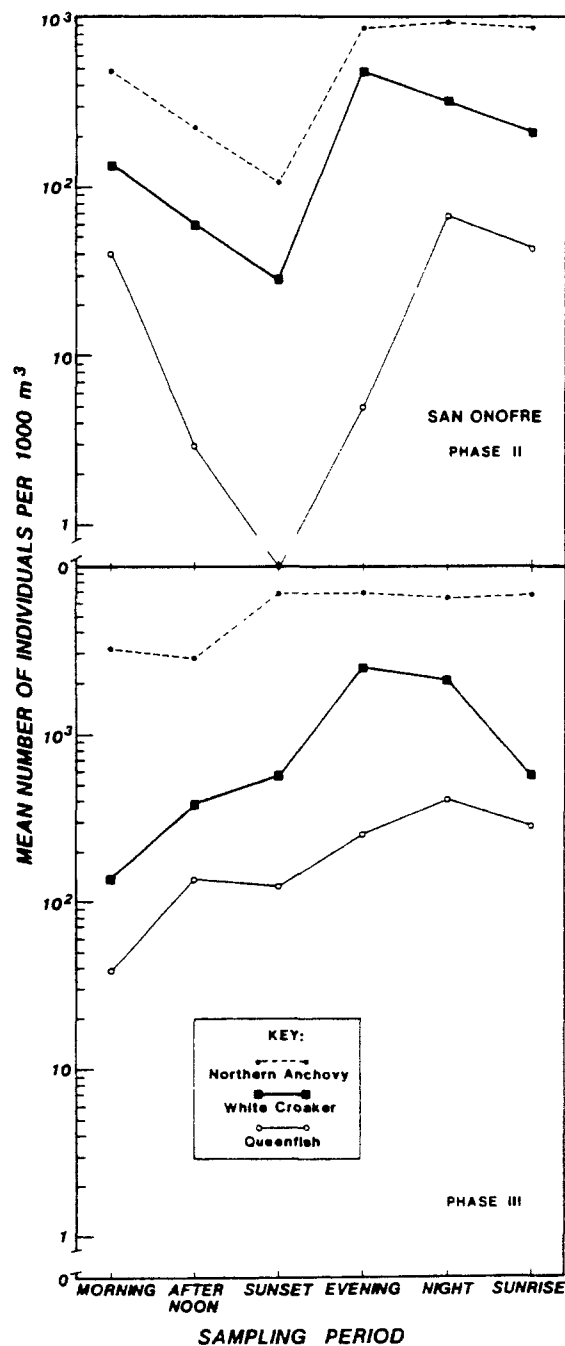


Figure 23. Comparative concentrations of target species larvae during two phases of winter mass balance studies at San Onofre Unit 1.

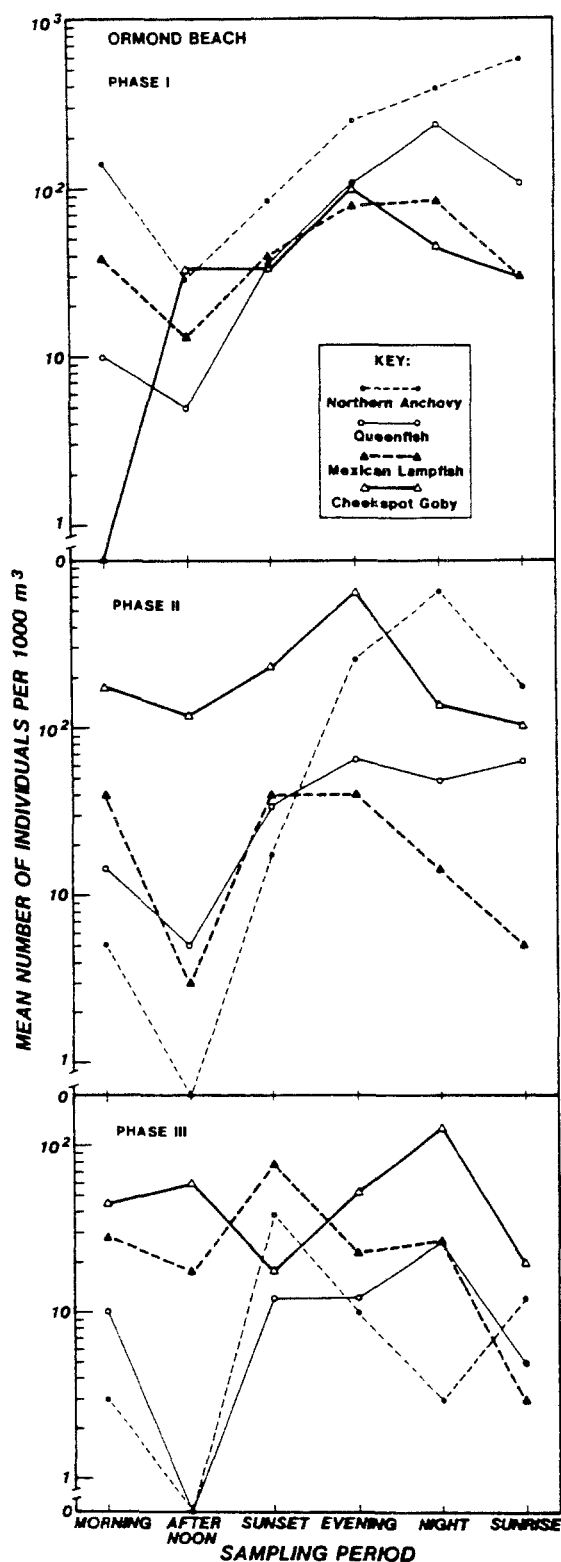


Figure 24. Comparative concentrations of target species larvae during three phases of summer mass balance studies at Ormond Beach.

Summer

Samples taken in mass balance studies conducted at Ormond Beach in September 1980 were generally dominated by four larval species: northern anchovy, cheekspot goby, queenfish, and Mexican lampfish, *Triphoturus mexicanus*.

Northern anchovy comprised 51.6% of the ichthyoplankton collected during Phase I. Maximum entrainment of anchovy occurred between evening and sunrise (2100 to 0630 hrs) with peak densities occurring just prior to and during sunrise. The temporal distribution of queenfish larvae, the second most abundant larvae collected in Phase I, was similar to that of northern anchovy, although peak entrainment occurred during the night sampling period (0100 to 0330 hrs; Figure 24). The remaining three major species collected during Phase I were Mexican lampfish, cheekspot goby, and Gobiidae Type D. These species comprised 9.5, 8.4, and 10.9% of the larval catch, respectively. Maximum concentrations of each species were recorded after sunset.

The larval community in Phase II was dominated by the larvae of cheekspot goby and northern anchovy. Together they represented approximately 69% of the larvae entrained. The density of both species increased substantially after sunset with the maximum entrainment of cheekspot goby larvae occurring during the evening sampling period (2100 to 2300 hrs), and northern anchovy occurring during the night sampling period (0100 to 0300 hrs). Other major larval species entrained included painted greenling, *Oxylebius pictus*, queenfish, and Mexican lampfish. Although painted greenling comprised 7.4% of the larvae collected, it appeared only in the first three samples collected during the sunset period. Larval queenfish densities increased substantially between sunset and sunrise sampling periods, with peak densities occurring at sunrise. Mexican lampfish were most abundant during the morning, sunset, and evening periods.

Larvae of cheekspot goby were the major species collected during Phase III, representing 36.1% of the larvae collected. Maximum concentrations were recorded during the night sampling period (0100 to 0330 hrs), while the lowest concentrations were recorded during sunset and sunrise periods. Larvae of Mexican lampfish, which represented approximately 21% of the catch, were the second most abundant species collected. Abundance of this species peaked during sunset, while the lowest densities were recorded during the sunrise sampling period.

Northern anchovy and queenfish were the only other larval species that contributed significantly to the ichthyoplankton community entrained during Phase III. Although northern anchovy and queenfish larvae composed 8.1 and 7.4% of the entrained community, respectively, their densities were substantially reduced in comparison to the densities recorded for each in the summer Phase I and Phase II studies. Both species were almost completely absent during daylight sampling periods, with maximum concentrations of northern anchovy larvae appearing in the sunset sampling period, and queenfish larvae in the night sampling period.

TRANSIT SUCCESS OF ENTRAINED LARVAE

Success of station transit by entrained larvae was calculated by comparing numbers of larvae taken in discharge collections to concentrations in intake samples, allowing a suitable lag time between the two for the sampled water parcel to pass through the cooling water system. Numbers of animals in discharge collections were compared to intake concentrations and expressed as a percentage of intake entrainment abundance.

Winter Mass Balance Studies - San Onofre Unit 1

Larvae of the three major target species experienced substantial cropping losses during station transit in both Winter Phase II and III Mass Balance Studies (Tables 17 and 18). Overall percentage of successful transit in the two phases was 13.9 and 10.8% for northern anchovy, 22.8 and 46.4% for white croaker, and 12.3 and 72.4% for queenfish (Tables 17 and 18). Changes in percent transit success between sampling periods did not appear to be related to the numbers of individuals entrained, as success during sampling periods displaying larger numbers of individuals varied during both phases. Sampling periods having median numbers of entrained individuals frequently had higher transit success ratios than periods with the highest number of entrained individuals.

Non-target species experienced varied success in station transit (Tables 19 and 20). Newly hatched yolk-sac larvae were taken in discharge samples at a rate of only 9.5% of intake concentrations during winter Phase II and 1.9% during Phase III. Larvae of California halibut/fantail sole and cheekspot goby were recovered with 14.9 and 27.8% success, respectively, during Phase II, and larvae of bay goby, Lepidogobius lepidus, and jacksmelt, Atherinopsis californiensis, enjoyed transit success percentages of 78.2 and 49.6%, respectively. Overall larval transit success was only 16.3% in Phase II and 19.1% in Phase III (Table 21).

Water column temperature profiles observed before sampling periods during both winter Phase II and III were relatively homogeneous, indicating that water column temperature and physical structure had little effect on transit success of entrained larvae. Mean transit success of combined Phase II and III samples between tidal cycles was not significantly different for two of three major target species when compared by Kruskal-Wallis one-way ANOVA (Siegel 1956).

Table 17. San Onofre Unit 1 mass balance study -- Winter Phase II (prior to heat treatment) 12-13 March 1980. Percent of transit success by size class [(discharge concentration + intake concentration) X 100].

Size Class (mm)	Period						Daily Total*
	Morning	Afternoon	Sunset	Evening	Night	Sunrise	
<u>E. mordax</u>							
0-3	6.7	5.2	2.8	7.6	6.6	7.0	6.5
3-6	10.1	6.1	4.2	12.1	9.3	10.1	9.5
6-9	36.2	19.9	20.8	23.6	14.0	18.2	20.0
9-12	51.6	56.4	27.9	24.0	13.8	20.8	22.5
12-15	39.5	65.0	22.2	32.1	16.8	14.2	24.5
15-18	57.1	68.8	26.7	31.7	8.9	15.8	28.5
18-21	50.0	33.3	37.5	23.2	37.5	5.3	24.2
21-24	>100.0	-	-	50.0	50.0	20.0	56.5
24-27	>100.0	-	-	14.3	0.0	-	31.0
27-30	-	-	-	0.0	-	-	0.0
Combined	15.9	16.1	10.2	20.4	10.3	13.6	13.9
Intake mean #/1000m ³	3034	1417	1090	4084	9002	6417	4281
<u>G. lineatus</u>							
0-3	23.6	25.5	3.8	32.0	24.1	15.1	24.9
3-6	0.0	0.0	33.3	77.8	5.6	25.0	45.5
6-9	0.0	0.0	>100.0	66.7	66.7	100.0	68.1
9-12	-	-	>100.0	37.5	20.0	0.0	38.9
12-15	-	-	-	>100.0	-	-	>100.0
Combined	22.8	25.0	36.4	38.6	24.2	15.4	22.8
Intake mean #/1000m ³	605	240	78	1295	2165	1348	1018
<u>S. politus</u>							
0-3	10.7	1.8	0.0	9.1	15.8	45.9	12.6
3-6	0.0	-	-	-	0.0	-	0.0
Combined	10.5	1.8	0.0	9.1	15.4	45.9	12.3
Intake mean #/1000m ³	381	140	20	55	438	93	222

* adjusted for day length

Additionally, a comparison of differences in mean transit success between sampling periods using the same test was not significant for any of the three major target species.

Summer Mass Balance Studies - Ormond Beach

Success of station transit for northern anchovy was much higher at Ormond Beach than was observed at San Onofre Unit 1 during Winter Mass Balance Studies (Figure 25). Transit success in Phase I was especially high in the 0 to 6 mm size groups, which had experienced extremely poor transit success in winter studies (Table 22). The observation that discharge concentrations of larvae were higher than intake concentrations in some replicates (transit success greater than 100%; Table 22) is probably due to the low numbers of larvae entrained, and the resulting high degree of variability induced by each occurrence. However, higher success rates were also observed in larger size classes where abundances were greater (Table 22). There was no clear trend of transit success related to intake concentration, as the period exhibiting highest concentrations (sunrise) also had one of the lowest success rates, and the period with the second-highest ranked abundances (night) had one of the highest success percentages.

Transit success of queenfish was lower at Ormond Beach than that observed at San Onofre during Winter Phase III samples, when larvae of 3 to 6 mm dominated the catch. While summer transit success rates for the 0 to 3 mm class were

Table 18. San Onofre Unit 1 mass balance study — Winter Phase III (after heat treatment), 26-27 March 1980. Percent of transit success by size class [(discharge concentration ÷ intake concentration) X 100].

Size Class (mm)	Period						Daily Total*
	Morning	Afternoon	Sunset	Evening	Night	Sunrise	
<u>E. mordax</u>							
0-3	6.0	8.6	4.5	1.2	1.6	2.7	3.4
3-6	5.4	11.9	10.3	2.4	16.8	18.9	9.5
6-9	47.8	20.0	82.7	40.4	25.4	86.5	36.0
9-12	>100.0	17.3	70.7	28.0	18.1	>100.0	33.5
12-15	>100.0	13.0	>100.0	21.8	27.6	>100.0	35.0
15-18	>100.0	50.0	46.7	15.3	20.9	83.0	35.3
18-21	>100.0	>100.0	100.0	9.1	18.2	>100.0	45.5
21-24	>100.0	0.0	>100.0	0.0	0.0	-	54.2
24-27	-	-	-	-	0.0	100.0	28.6
27-30	>100.0	-	-	-	-	-	>100.0
Combined	13.0	11.9	11.5	9.4	7.5	13.5	10.8
Intake mean #/1000m ³	3203	2833	6964	6995	6412	6914	4984
<u>G. lineatus</u>							
0-3	14.7	20.0	13.4	20.0	7.2	12.8	14.4
3-6	>100.0	97.3	>100.0	34.4	35.9	>100.0	51.9
6-9	>100.0	-	100.0	12.5	61.2	>100.0	57.7
9-12	0.0	>100.0	-	-	100.0	-	37.0
12-15	-	-	>100.0	-	-	-	>100.0
Combined	>100.0	57.8	39.2	32.8	32.1	>100.0	46.4
Intake mean #/1000m ³	143	385	568	2566	2091	583	1092
<u>S. politus</u>							
0-3	37.5	17.0	13.9	9.7	17.7	13.6	16.4
3-6	100.0	93.3	>100.0	>100.0	39.9	>100.0	95.5
6-9	-	-	>100.0	-	-	-	>100.0
9-12	-	-	-	-	0.0	-	0.0
Combined	66.7	37.4	60.8	80.0	36.0	>100.0	72.4
Intake mean #/1000m ³	38	141	128	266	416	285	201

* adjusted for day length

comparable to northern anchovy (no doubt due to similar circumstances, discussed above), rates in the 3 to 6 mm class were much lower, and were responsible for the lowered success rate. As was noted for northern anchovy, sampling periods with highest numbers of entrained larvae were characterized by success rates that were among the lowest observed during the study. No larvae of white croaker were observed in Summer Phase I intake or discharge samples.

Overall transit success of entrained larvae during summer Phase I was 59.5% (Table 23). Transit success of abundant non-target species varied. Larvae of Mexican lampfish, cheekspot goby and blennies experienced 30.3, 8.4, and 41.9% transit success, respectively. A high percentage of transit success was noted for hornhead turbot, *Pleuronichthys verticalis*, and unidentified turbot (*Pleuronectidae*), while California halibut/fantail sole and Gobiidae type D experienced only moderate success. The majority of species were taken in intake but not discharge samples, although in a small number of cases the opposite pattern was observed.

Transit success of northern anchovy was slightly higher in summer Phase II than in summer Phase I (Table 24), due to the combination of higher survival rates of large larvae coupled with absence of smaller size groups (Table 24). Periods with highest abundance were characterized by higher overall survival

Table 19. Intake and discharge daily larval entrainment*. San Onofre Unit 1 mass balance study - Winter Phase II (prior to heat treatment), 12-13 March 1980.

Species	Concentration		% Transit Success
	Intake	Discharge	
<i>Engraulis mordax</i> **	8,181,946	1,139,548	13.9
<i>Bathylagidae</i> , unid.	-	1,003	>100.0
<i>Gobiesox rhessodon</i>	2,007	-	0.0
<i>Atherinopsis californiensis</i>	98,369	48,826	49.6
<i>Seriphus politus</i> **	426,965	52,648	12.3
<i>Genyonemus lineatus</i> **	1,946,497	444,757	22.8
<i>Cheilotrema saturnum</i> **	2,389	1,003	42.0
<i>Clinidae</i> , unid.	1,003	2,007	>100.0
<i>Heterostichus rostratus</i>	4,395	3,010	68.5
<i>Gibbonsia</i> sp. A	23,601	7,166	30.4
<i>Hypsoblennius</i> spp.	23,266	5,399	23.2
<i>Gobiidae</i> , unid.	16,960	4,539	26.8
<i>Typhlogobius californiensis</i>	-	1,003	>100.0
<i>Ilypnus gilberti</i>	110,695	30,834	27.9
<i>Lepidogobius lepidus</i>	71,806	56,136	78.2
<i>Gobiidae</i> type D	2,389	-	0.0
<i>Peprilus simillimus</i> **	6,402	-	0.0
<i>Paralichthys californicus</i>	-	3,392	>100.0
<i>Citharichthys</i> spp.	1,003	-	0.0
<i>Paralichthys californicus</i> / <i>Xystreurus tolepis</i>	111,507	16,578	14.9
<i>Pleuronectidae</i> , unid.	2,007	-	0.0
<i>Hypsopsetta guttulata</i>	38,650	4,013	10.4
<i>Pisces</i> larvae, unid.	486,732	148,819	30.6
<i>Pisces</i> yolk sac larvae	1,249,221	118,310	9.5
Total Larvae	12,807,810	2,088,091	16.3

* based on maximum intake flow rates from Schlotterbeck et al. 1979 (SCE R&D Ser. 79-RD-68)

**316(b) target species

Table 20. Intake and discharge daily larval concentrations* San Onofre Unit 1 mass balance study - Winter Phase III (after heat treatment), 26-27 March 1980.

Species	Concentration		% Transit Success
	Intake	Discharge	
<i>Engraulis mordax</i> **	9,524,758	1,026,422	10.8
<i>Stenobranchius leucopsarus</i>	908	1,003	>100.0
<i>Gobiesox rhessodon</i>	48,109	24,174	50.2
<i>Rimicola</i> sp. A	382	-	0.0
<i>Atherinopsis californiensis</i>	28,474	2,771	9.7
<i>Paralabrax</i> spp.	2,484	-	0.0
<i>Seriphus politus</i> **	383,681	277,773	72.4
<i>Genyonemus lineatus</i> **	2,087,767	968,586	46.4
<i>Cheilotrema saturnum</i> **	4,777	-	0.0
<i>Atractoscion nobilis</i>	1,672	-	0.0
<i>Clinidae</i> , unid.	-	382	>100.0
<i>Heterostichus rostratus</i>	7,787	382	4.9
<i>Gibbonsia</i> sp. A	3,631	3,392	93.4
<i>Hypsoblennius</i> spp.	20,782	7,692	37.0
<i>Gobiidae</i> , unid.	-	3,535	>100.0
<i>Typhlogobius californiensis</i>	7,310	3,392	46.4
<i>Quietula y-cauda</i>	-	1,003	>100.0
<i>Ilypnus gilberti</i>	13,616	14,619	>100.0
<i>Lepidogobius lepidus</i>	38,554	34,876	90.5
<i>Gobiidae</i> type D	3,774	764	20.2
<i>Peprilus simillimus</i> **	20,543	-	0.0
<i>Paralichthys californicus</i>	1,815	2,771	>100.0
<i>Citharichthys</i> spp.	1,672	-	0.0
<i>Paralichthys californicus</i> / <i>Xystreurus tolepis</i>	21,738	382	1.7
<i>Hypsopsetta guttulata</i>	7,262	4,395	60.5
<i>Parophrys vetulus</i>	382	-	0.0
<i>Pisces</i> larvae, unid.	170,557	122,844	72.0
<i>Pisces</i> yolk sac larvae	745,768	14,046	1.9
Total Larvae	13,148,203	2,515,204	19.1

* based on maximum intake flow rates from Schlotterbeck et al. 1979 (SCE R&D Ser. 79-RD-68)

**316(b) target species

Table 21. San Onofre Unit 1 mass balance studies-Percent transit success (Winter Phases II and III).

Species	Common Name	Overall Mean/1000 m ³	Rank	Phase		Combined
				II	III	
Total Larvae		6791.2		16.3	19.1	18.5
<i>Engraulis mordax</i> *	northern anchovy	4632.8	1	13.9	10.8	12.2
<i>Genyonemus lineatus</i> *	white croaker	1055.6	2	22.8	46.4	35.0
Fishes yolk sac larvae	yolk sac larvae	522.0	3	9.5	1.9	6.6
<i>Seriphus politus</i> *	queenfish	212.1	4	12.3	72.4	40.9
Fishes larvae, unid.	fragments and mutilated	172.0	5	30.6	72.0	41.3
<i>Paralichthys californicus</i> /	California halibut/					
<i>Xystreus liolepis</i>	fantail sole	34.9	6	14.9	1.7	12.7
<i>Atherinops californiensis</i>	jacksmelt	33.2	7	49.6	9.7	40.6
<i>Illypnus gilberti</i>	cheekspot goby	32.5	8	27.9	>100.0	36.5
<i>Lepidogobius lepidus</i>	bay goby	28.9	9	78.2	90.5	82.4
<i>Gobiosox rhessodon</i>	California clingfish	13.1	10	0.0	50.2	48.2
<i>Hypsopsetta guttulata</i>	diamond turbot	12.0	11	10.4	60.5	18.3
<i>Hypsoblennius</i> spp.	blenny	11.5	12	23.2	37.0	29.7
<i>Gibbonia</i> sp. A	kelpfish	7.1	13	30.4	93.4	38.7
<i>Peprilus similimus</i> *	Pacific butterfish	7.1	14	0.0	0.0	0.0
Gobiidae, unid.	goby	4.4	15	26.8	>100.0	47.5
<i>Heterostichus rostratus</i>	giant kelpfish	3.2	16	68.5	4.9	27.8
<i>Typhlogobius californiensis</i>	blind goby	1.9	17	>100.0	46.4	60.2
<i>Cheilotrema saturnum</i> *	black croaker	1.9	18	42.0	0.0	1.4
Gobiidae type D	goby	1.6	19	0.0	20.2	12.4
<i>Citharichthys</i> spp.	sand dab	0.7	20	0.0	0.0	0.0

* 316(b) target species

rates in the latter survey. As discussed previously, survival rates greater than 100% were most often the result of sporadic occurrences of larvae.

The only size group of larval queenfish to survive transit was the 3 to 6 mm size class, which comprised 85% of all queenfish taken. Transit success rates were not related to the entrainment sampling period. While overall transit success was substantially lower than that observed during summer Phase I sampling, the percent transit success for the 3 to 6 mm class was almost identical during both phases.

Transit success for the entire larval assemblage was lower during summer Phase II than in summer Phase I (Table 25). Non-target species entrained in substantial numbers experienced transit success ranging from 26.4% in cheekspot goby to 0.9% in painted greenling, 58.8% in Mexican lampfish, 9.3% in unidentified Gobiidae, and 35.0% in longjaw mudsucker, *Gillichthys mirabilis*. Flatfish larvae fared especially poorly in summer Phase II compared to summer Phase I. As was observed in Phase I, a majority of larval species

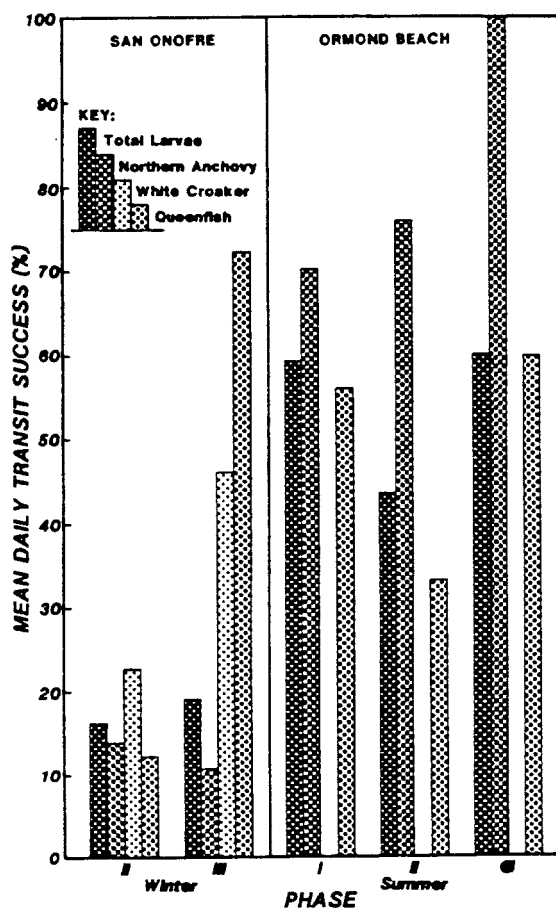


Figure 25. Comparative percent transit success of three target species and total larvae during two winter and three summer mass balance studies.

Table 22. Ormond Beach mass balance study — Summer Phase I (Mid-cycle), 3-4 September 1980. Percent of transit success by size class [(discharge concentration + intake concentration) X 100].

Size Class (mm)	Period						Daily Total*
	Morning	Afternoon	Sunset	Evening	Night	Sunrise	
<u>E. mordax</u>							
0-3	>100.0	>100.0	-	>100.0	>100.0	75.0	>100.0
3-6	53.2	37.5	>100.0	55.5	77.0	54.2	63.3
6-9	28.6	0.0	-	25.0	62.5	10.5	30.3
9-12	>100.0	>100.0	>100.0	88.8	43.7	82.3	78.9
12-15	100.0	0.0	46.1	92.5	>100.0	>100.0	95.6
15-18	0.0	-	70.0	73.6	>100.0	35.2	67.7
18-21	-	-	>100.0	>100.0	-	0.0	95.6
21-24	-	-	-	>100.0	-	-	>100.0
24-27	-	-	-	-	-	0.0	0.0
Combined	57.4	54.5	85.2	75.2	79.7	55.9	70.2
Intake mean #/1000m ³	148	28	85	253	393	586	213
No <u>Geryonemus lineatus</u> were collected in intake or discharge samples.							
<u>S. politus</u>							
0-3	>100.0	>100.0	100.0	66.7	>100.0	70.8	>100.0
3-6	50.0	>100.0	90.9	27.5	19.9	23.8	33.8
6-9	-	-	-	0.0	-	>100.0	22.2
Combined	100.0	>100.0	92.8	28.8	57.5	51.1	56.0
Intake mean #/1000m ³	10	5	35	113	236	113	79.5

* adjusted for day length

Table 23. Intake and discharge daily larval concentrations* — Ormond Beach mass balance study — Summer Phase I (Mid-cycle), 3-4 September 1980.

Species	Concentration		% Transit Success
	Intake	Discharge	
<u>Engraulis mordax</u> **	585,816	411,277	70.2
<u>Myctophidae</u> , unid.	-	19,782	>100.0
<u>Triphoturus mexicanus</u>	126,218	38,267	30.3
<u>Lampanyctus</u> sp.	519	-	0.0
<u>Otophidium scrippsi</u>	1,362	-	0.0
<u>Paralabrax clathratus</u> **	6,486	-	0.0
<u>Paralabrax</u> spp.	3,243	7,005	>100.0
<u>Seriphus politus</u> **	228,113	127,644	56.0
<u>Paraclinus integripinnis</u>	-	2,400	>100.0
<u>Gibbonsia</u> sp. A	2,724	-	0.0
<u>Neoclinus</u> sp. A	2,724	-	0.0
<u>Hypsoblennius</u> spp.	30,484	12,777	41.9
<u>Gobiidae</u> , unid.	14,983	27,955	>100.0
<u>Coryphopterus nicholsii</u>	6,810	1,362	20.0
<u>Ilypnus gilberti</u>	109,678	9,210	8.4
<u>Lepidogobius lepidus</u>	1,362	-	0.0
<u>Gobiidae</u> Type D	4,605	1,362	29.6
<u>Gillichthys mirabilis</u>	1,362	-	0.0
<u>Oxylebius pictus</u>	519	1,038	>100.0
<u>Cottidae</u> , unid.	-	1,362	>100.0
<u>Cottidae</u> Type 7	-	1,362	>100.0
<u>Paralichthys californicus</u>	10,053	1,362	13.5
<u>Citharichthys</u> spp.	3,243	-	0.0
<u>Paralichthys californicus</u> / <u>Xystreurus tirolepis</u>	9,210	3,243	35.2
<u>Pleuronectidae</u> , unid.	5,124	2,400	46.8
<u>Pleuronichthys verticalis</u>	4,605	3,762	81.7
<u>Hypsopsetta guttulata</u>	2,724	1,362	50.0
<u>Parophrys vetulus</u>	1,362	-	0.0
<u>Pleuronichthys</u> sp.	1,362	-	0.0
<u>Symphurus atricauda</u>	1,362	-	0.0
<u>Pisces</u> larvae, unid.	49,748	48,515	97.5
<u>Pisces</u> yolk sac larvae	3,243	1,362	42.0
Total Larvae	1,219,044	724,809	59.5

* based on maximum intake flow rates from Schlotterbeck et al. 1979 (SCE R&D Ser. 79-RD-68)

**316(b) target species

Table 24. Ormond Beach mass balance study — Summer Phase II (Pre-heat), 22-23 September 1980. Percent of transit success by size class [(discharge concentration + intake concentration) X 100].

Size Class (mm)	Period						Daily Total*
	Morning	Afternoon	Sunset	Evening	Night	Sunrise	
<u>E. mordax</u>							
0-3	>100.0	-	-	>100.0	-	-	>100.0
3-6	-	-	-	-	-	-	-
6-9	-	-	-	-	-	-	-
9-12	-	>100.0	>100.0	-	64.0	>100.0	>100.0
12-15	>100.0	>100.0	>100.0	74.0	69.0	>100.0	82.0
15-18	>100.0	-	>100.0	41.0	61.2	>100.0	63.0
18-21	-	-	-	0.0	>100.0	33.3	>100.0
Combined	>100.0	>100.0	>100.0	55.3	69.4	>100.0	76.1
Intake mean #/1000m ³	5	0	18	258	649	178	202
<u>G. lineatus</u>							
0-3	-	0.0	-	-	-	-	0.0
Combined		0.0					0.0
Intake mean #/1000m ³		2.4					0.5
<u>S. politus</u>							
0-3	-	-	-	0.0	0.0	-	0.0
3-6	40.0	100.0	20.0	48.0	38.0	19.2	39.2
6-9	0.0	-	0.0	0.0	0.0	-	0.0
Combined	33.3	100.0	14.2	38.4	31.6	19.2	33.3
Intake mean #/1000m ³	15	5	35	65	47	65	35

* adjusted for day length

Table 25. Intake and discharge larval concentrations* — Ormond Beach mass balance study, Summer Phase II (Pre-heat), 22-23 September 1980.

Species	Concentration		% Transit Success
	Intake	Discharge	
<i>Engraulis mordax</i> **	536,807	408,423	76.1
<i>Triphoturus mexicanus</i>	62,460	36,711	58.8
<i>Rimicola muscarum</i>	1,362	-	0.0
Gobiesocidae type A	1,362	-	0.0
<i>Gobiesox rhessodon</i>	-	1,038	>100.0
<i>Paralabrax clathratus</i> **	1,038	-	0.0
<i>Paralabrax</i> spp.	-	1,362	>100.0
Sciaenidae, unid.	1,362	-	0.0
<i>Seriphus politus</i> **	92,808	30,873	33.3
<i>Genyonemus lineatus</i> **	1,226	-	0.0
<i>Roncador stearnsi</i> **	1,362	-	0.0
<i>Oxyjulis californica</i>	1,362	-	0.0
<i>Paralichthys integrifinnis</i>	-	6,810	>100.0
<i>Gibbonsia</i> sp. A	3,762	1,362	36.2
<i>Neoclinus</i> sp. A	1,362	-	0.0
<i>Hypsoblennius</i> spp.	26,709	2,724	10.2
Gobiidae, unid.	58,698	5,448	9.3
<i>Ilypnus gilberti</i>	666,793	176,289	26.4
<i>Lepidogobius lepidus</i>	14,788	2,724	18.4
Gobiidae type D	1,557	1,881	>100.0
<i>Gillichthys mirabilis</i>	40,927	14,334	35.0
<i>Oxylebius pictus</i>	56,558	519	0.9
<i>Paralichthys californicus</i>	519	-	0.0
<i>Paralichthys californicus</i> / <i>Xystreurus liolepis</i>	1,362	-	0.0
<i>Hippoglossina stomata</i>	-	1,362	>100.0
<i>Hypsopsetta guttulata</i>	4,086	519	12.7
Pisces larvae, unid.	47,075	19,263	40.9
Pisces yolk sac larvae	3,950	1,881	47.6
Total Larvae	1,630,657	713,523	43.8

* based on maximum intake flow rates from Schlotterbeck et al. 1979 (SCE R&D Ser. 79-RD-68)

**316(b) target species

were collected from the intake but not the discharge, although in some cases the reverse was again observed.

Overall concentrations of northern anchovy entrained during summer Phase III were so low, and the resulting variability of occurrence so great, that total transit success of anchovy was greater than 100% (Table 26). Only during the sunset period were transit success percentages of less than 100% observed in conjunction with higher larval concentrations. Overall success of each of the nighttime and sunrise periods was greater than or equal to 100%. The majority of large larvae were taken during these periods, resulting in transit success of greater than 100% for all larvae greater than 9 mm (Table 26).

Larvae of queenfish were only slightly more abundant than northern anchovy, but were dominated by individuals in the 3 to 6 mm size class. Overall transit success of that class was 60.7%, slightly higher than the total species success percentage of 59.9%. As was observed for northern anchovy, the lowest success percentage by period for queenfish was noted during the period of highest substantial abundance.

Overall transit success for all larvae entrained during Phase III was the highest of the summer mass balance studies (Table 27), and corresponded closely to the success of the top four entrained species. Percent transit success of abundant non-target species ranged from 50.2% for cheekspot goby to 55.1% for Mexican lampfish. Numbers of species taken in the intake but not in the discharge was substantially lower than in the previous two phases (Table 28).

A least-squares regression analysis of overall percent transit success versus entrainment abundance for the five mass balance studies indicated a strong inverse relationship between density of entrained larvae and success of station transit. The regression line (Figure 21) displayed an r^2 value of 0.928, indicating a significant correlation at $p = 0.001$.

Table 26. Ormond Beach mass balance study — Summer Phase III (Post-heat), 29-30 September 1980. Percent of transit success by size class [(discharge concentration + intake concentration) X 100].

Size Class (mm)	Period						Daily Total*
	Morning	Afternoon	Sunset	Evening	Night	Sunrise	
<u>E. mordax</u>							
0-3	0.0	-	-	-	-	-	0.0
3-6	-	-	0.0	-	-	-	0.0
6-9	-	-	16.7	0.0	-	-	11.8
9-12	-	-	66.7	>100.0	>100.0	>100.0	>100.0
12-15	-	-	>100.0	100.0	>100.0	>100.0	>100.0
15-18	-	-	100.0	100.0	>100.0	>100.0	>100.0
18-21	-	-	>100.0	-	>100.0	>100.0	>100.0
21-24	-	-	-	-	>100.0	>100.0	>100.0
Combined	0.0	-	64.3	100.0	>100.0	>100.0	>100.0
Intake mean #/1000m ³	3	0	35	10	3	13	7
No <u>Geryonemus lineatus</u> were collected in intake or discharge samples.							
<u>S. politus</u>							
0-3	0.0	-	-	-	-	0.0	0.0
3-6	66.7	-	40.0	100.0	28.1	>100.0	60.7
6-9	-	-	-	100.0	-	-	100.0
9-12	-	-	-	-	-	-	-
12-15	-	-	-	>100.0	-	-	>100.0
Combined	50.0	-	40.0	>100.0	28.1	>100.0	59.9
Intake mean #/1000m ³	10	0	13	13	27	5	10

* adjusted for day length

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Table 27. Intake and discharge daily concentrations* — Ormond Beach mass balance study. Summer Phase III (Post-heat), 29-30 September 1980.

Species	Concentration		% Transit Success
	Intake	Discharge	
<i>Engraulis mordax</i> **	19,525	38,851	>100.0
<i>Triphoturus mexicanus</i>	67,592	37,230	55.1
Gobiessocidae Type A	-	519	>100.0
<i>Paralabrax clathratus</i> **	4,671	-	0.0
<i>Seriphus politus</i> **	29,323	17,577	59.9
<i>Hypsoblennius</i> spp.	15,177	7,329	49.3
Gobiidae, unid.	6,748	6,810	>100.0
<i>Coryphopterus nicholsii</i>	6,229	2,724	43.7
<i>Ilypnus gilberti</i>	156,861	78,740	50.2
Gobiidae Type D	24,391	12,972	53.2
<i>Gillichthys mirabilis</i>	19,073	7,848	41.1
<i>Oxylebius pictus</i>	-	1,038	>100.0
<i>Citharichthys</i> spp.	3,114	5,448	>100.0
Pisces larvae, unid.	14,532	5,319	36.6
Pisces yolk sac larvae	4,476	1,362	30.4
Total Larvae	371,712	223,857	60.2

* based on maximum intake flow rates from Schlatterbeck et al. 1979 (SCE R&D Ser. 79-RD-68)

**316(b) target species

Table 28. Ormond Beach mass balance studies — Percent larval transit success (Summer Phases I through III).

Species	Common Name	Overall Mean/1000 m ³	Rank	Phase			Combined
				I	II	III	
Total Larvae		413.9		59.5	43.8	60.2	51.6
<i>Engraulis mordax</i> *	northern anchovy	146.7	1	70.2	76.1	>100.0	75.2
<i>Ilypnus gilberti</i>	cheekspot goby	119.9	2	8.4	26.4	50.2	28.3
<i>Seriphus politus</i> *	queenfish	45.0	3	56.0	33.3	59.9	50.2
<i>Triphoturus mexicanus</i>	Mexican lampfish	32.9	4	30.3	58.8	55.1	43.8
Pisces larvae, unid.	fragments and mutilated	14.3	5	97.5	40.9	36.6	65.7
Gobiidae, unid.	gobies	10.3	6	>100.0	9.3	>100.0	50.2
<i>Hypsoblennius</i> spp.	blennies	9.3	7	41.9	10.2	49.3	33.3
<i>Gillichthys mirabilis</i>	longjaw mudsucker	7.9	8	0.0	35.0	41.1	36.2
<i>Oxylebius pictus</i>	painted greenling	7.3	9	>100.0	0.9	>100.0	4.5
Gobiidae Type D	goby	3.9	10	29.6	>100.0	53.2	52.9
<i>Lepidogobius lepidus</i>	bay goby	2.1	11	0.0	18.4	-	16.9
<i>Coryphopterus nicholsii</i>	blackeye goby	1.7	12	0.2	-	43.7	31.0
<i>Paralabrax clathratus</i> *	kelp bass	1.6	13	0.0	0.0	0.0	0.0
Pisces yolk sac larvae	yolk sac larvae	1.5	14	42.0	47.6	30.4	39.3
<i>Paralichthys californicus</i>	California halibut	1.4	15.5	13.5	0.0	-	12.5
<i>Paralichthys californicus</i> /	California halibut/						
<i>Xystreurus tolepis</i>	fantail sole	1.4	15.5	35.2	0.0	-	30.9
<i>Hypsopsetta guttulata</i>	diamond turbot	0.9	17	50.0	12.7	-	27.8
<i>Gibbonsia</i> sp. A	kelpfish	0.8	18	0.0	36.2	-	20.5
<i>Citharichthys</i> spp.	sand dab	0.8	19	0.0	-	>100.0	85.4
<i>Pleuronectidae</i> , unid.	flatfish	0.7	20	46.8	-	-	46.8

* 316(b) target species

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